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DISPOSAL SYSTEMS AND TECHNIQUES FOR OIL AND HAZARDOUS CHEMICALS--ETC(U)

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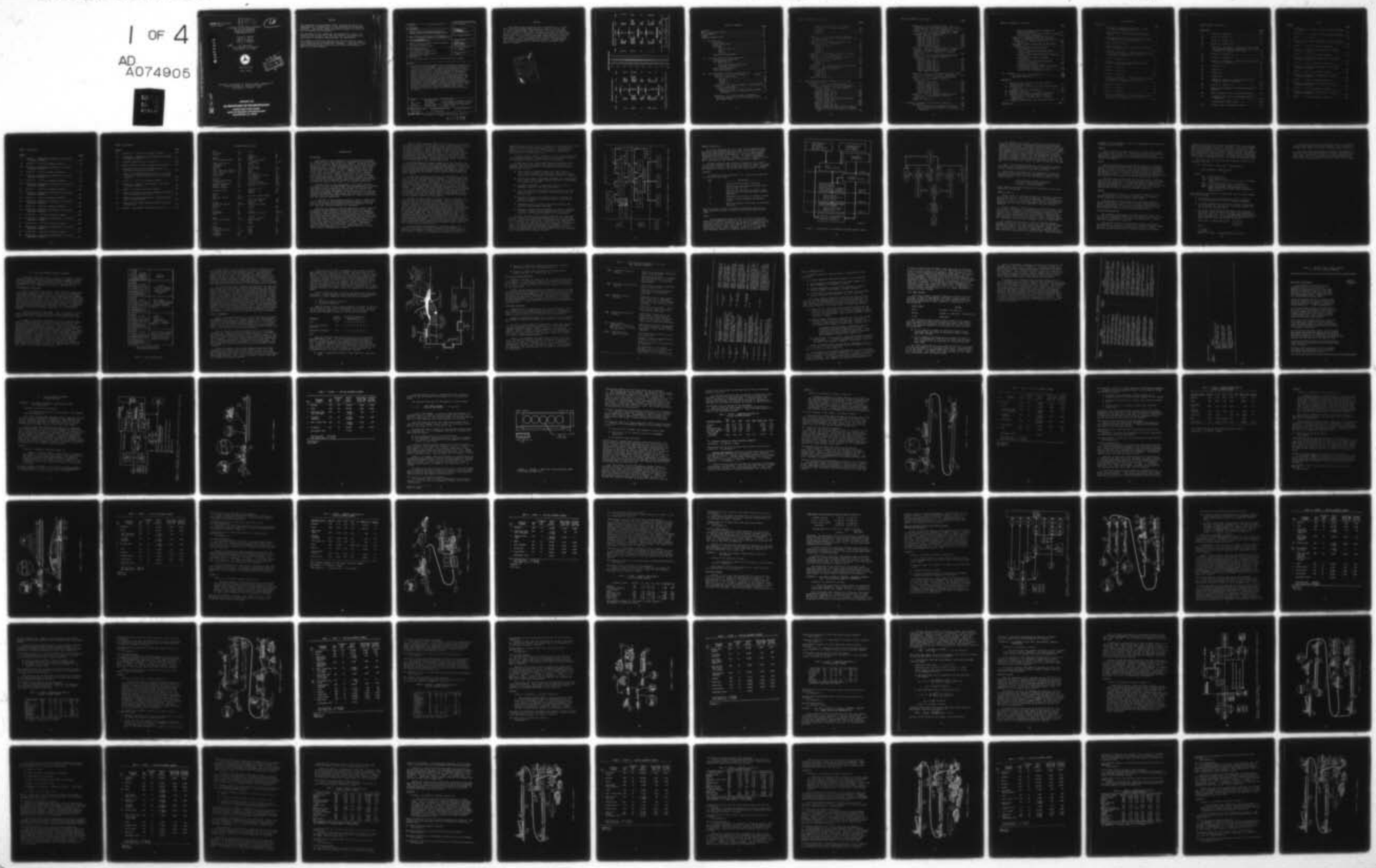

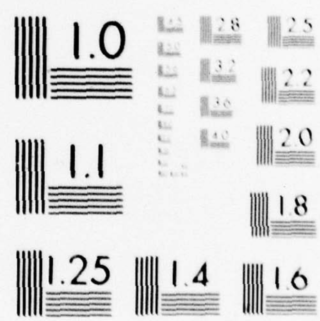

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REPORT NO. CG-D-35-79
Task No. 4153.2

DISPOSAL SYSTEMS AND TECHNIQUES FOR OIL AND HAZARDOUS CHEMICALS RECOVERED FROM MARINE SPILLS

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February 1979

FINAL REPORT

PREPARED FOR

U.S. DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD
OFFICE OF RESEARCH AND DEVELOPMENT
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U.S. Coast Guard Project Officer for this effort was John R. Sinclair

16. Abstract

Existing and conceptual equipment systems are presented for transport and disposal of spill cleanup debris. Each system is categorized and discussed in terms of possible operational conditions, applicability to different types of oils and chemicals, and capacity for the solid debris constituent. Additional data include cost, dimensions and weights of key equipment elements, transportability, and crew requirements. For oil spills, 13 disposal equipment systems (plus four auxiliary systems) are summarized based on literature and descriptions of past disposal experiences. Many floating and hazardous chemical spill debris may also be handled by the described systems, although some modification is necessary to prevent recontamination of the environment, hazards to the crew, and deterioration of equipment. Conceptual methods for handling of hazardous wastes include special truck-towable containers and field-sealable bags. The oils and chemicals listed in the U.S. Coast Guard Chemical Hazards Response Information System (CHRIS: CG-446-1, Jan. 1974) are used as a basis for this study.

17. Key Words

Oil
Spill debris
Disposal
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PREFACE

The authors wish to express their gratitude to U.S. Coast Guard Technical Project Representative, John R. Sinclair, and all other involved Coast Guard officials for their assistance in the execution of this work. We would also like to thank LCDR John H. Wiechert, USCG (Ret) of Clean Sound Cooperative (Seattle, Washington) for his timely review and suggestions for technical improvement. Finally, we make special note of the many equipment manufacturers, representatives and spill clean-up experts who gladly provided much of the information upon which this report is based.

METRIC CONVERSION FACTORS

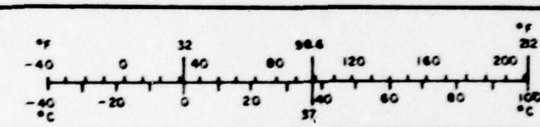
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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TABLES (continued)

STANDARD ABBREVIATIONS

acre	ac
acre feet	ac ft
ampere	A
barrel	bbl
British thermal unit	Btu
center of gravity	CG
centimeter	cm
coulomb	C
cubic ft	ft^3
cubic feet per minute	cfm
cubic feet per second	cfs
cubic meter	m^3
cubic yard	yd^3
decibel	dB
degrees centigrade (Celsius)	^oC
degrees Fahrenheit	^oF
degrees Kelvin	^oK
degrees Rankine	^oR
electron volts	eV
farad	F
feet	ft
feet per second	ft/sec
foot	ft
gallon	gal
gallon per minute	gal/min
gravity	g
gram	g
hectare	ha
horsepower	hp
hour	hr
inch	in
inches per second	in/sec
joule	J
kilo	k
kilogram	kg
kilogram per cubic meter	kg/m^3
kilometer	km
kilowatt	kw
liter	ℓ
mega	M
megawatt	MW
meter	m
meter per second squared	m/sec^2
metric ton	t
micro	μ
microfarad	μF
microsecond	μsec
mile	mi
milli	m
milligram	mg
milligrams per liter	mg/ℓ
millimeter	mm
millisecond	msec
millivolt	mV
million gallons	MG
million gallons/day	mgd
minute	min
nautical mile	nmi
newton	N
number	No.
ohm (not abbreviated)	
parts per million	ppm
per cubit foot	pcF
pound	lb
pounds per square inch	psi
quart	qt
radian	rad
radian per second	rad/sec
second	sec
specific gravity	s.g.
square meter	m^2
ton	ton
tonne	t
volts	V
watt	W
week	wk
yard	yd
year	yr

I. INTRODUCTION

BACKGROUND

Development of the technology for containment and removal of spilled oils has been generously supported by the government and private industry during the last decade. Following the Santa Barbara oil spill in 1969, government and industry have devoted increased efforts towards safeguarding against oil spills, and towards methods for rapid oil spill cleanup should those safeguards fail. For example, most oil companies have formed and joined cooperatives to respond to oil spills in U.S. harbors. As a result, oil spill cleanup cooperatives and increasingly specialized contractors now have access to a variety of innovative containment booms, skimmers, and other recovery equipment. The availability of improved hardware has enabled more rapid containment and improved efficiency in oil recovery operations.

Another factor in the improvement of oil spill response efficiency has been the development and implementation of regional contingency plans, mandated by the national Oil and Hazardous Substances Pollution Contingency *Plan (40 C.F.R. 1510)*. By specifying emergency procedures and the disposition of available manpower and equipment, these plans have resulted in stepped-up response times and coordinated approaches to large-scale containment and recovery operations.

In addition to these planning efforts, the U.S. Coast Guard (USCG) and the U.S. Environmental Protection Agency (EPA) have and are investigating new technologies for recovering spilled oils and other floating chemicals or substances.

Congress has recently directed appropriate federal agencies to develop suitable methods for hazardous and toxic material management (Toxic Substances Control Act, Public Law 94-469; and the Resource Conservation and Recovery Act, Public Law 94-580). Since many hazardous chemicals are shipped by water carrier, the Coast Guard must be prepared to properly clean up the inevitable spills that occur during transport of these materials, and to effectively dispose of the material and associated debris collected along with the spilled material itself. (Recovered spilled components, including water, and associated solid materials are referred to as "spill cleanup debris," or simply "spill debris," throughout this report).

Many of these hazardous materials are soluble when spilled and readily dispersed in the water column, making recovery efforts extremely difficult. Other difficult-to-recover pollutants include sinkables and vapors emitted from the exposed surfaces of spilled material. While the state of the art of recovery equipment for these types of materials is less advanced than for oil and other floating chemicals, there are some devices and methods which have been used with success to recover certain hazardous non-floatables. One example is the carbon filtration trailer developed by EPA, Edison, New Jersey.

As containment and recovery technologies are improved, the capability for handling greater amounts and broader varieties of spill debris in a given spill event becomes apparent. The result will be increased need for methodologies addressed to proper handling and disposal hardware, with special emphasis directed toward minimizing the adverse impacts upon the environment and public health.

In the past, efforts to clean up oil and hazardous material spills have not been completely systematic. In particular, the crucial step of ultimate disposal for the recovered material has been given low priority. Spill debris is often collected and stockpiled (often improperly) before serious efforts are undertaken to identify disposal alternatives or to select disposal methods. For example, debris collected following the M/T Pennant spill in Narragansett Bay, Rhode Island (1973), was stockpiled in a parking lot for almost one year before a land disposal site was secured. While more sophisticated cleanup methods are presently employed, there has been little or no attention devoted to the ultimate disposal of spill debris.

In many instances, debris disposal sites or techniques have been selected in the rush of the moment. There is generally insufficient time to evaluate the suitability of alternative disposal options in the area, and to choose the one that offers the best conditions for environmental protection. Furthermore, most localities do not now have qualified personnel available who have sufficient knowledge of the particular factors that must be considered when selecting a disposal method or site for oil or hazardous chemicals. All too often, combustible debris is improperly burned in the open, creating smoke and odors. Health problems could result from such practices if spill debris contain hazardous substances. In the long term, if not disposed of properly, the spill debris itself, or its residue after processing, could conceivably be a source of environmental damage equal to that caused by the original spill.

To ensure that environmentally acceptable methods are applied to all debris disposal situations, the methods must be readily implementable and understood by all persons responsible for disposal. Ideally, government and industry officials in

areas where spills have occurred, and/or could be expected to occur, should predetermine which disposal methods or sites are best suited for each specific spill debris type. A contingency disposal action plan could then be followed which would allow for deliberate, rational decisions.

To date, however, ideal conditions have not been encountered. Local and regional spill cleanup plans have completely omitted or inadequately addressed debris disposal procedures.

In many past cases, the disposal problems have been difficult, and solutions occasionally less than satisfactory. For example, some of the problems associated with proper handling and disposal include:

- Solid materials present in the spill debris (e.g., sand, aquatic plants, sorbents) can clog pumps; larger solids can require special or manual handling procedures.

- Insufficient and/or inadequate equipment for transferring spill debris from primary recovery devices to transportation vessels or vehicles.

- Inadequate temporary storage facilities for oily or hazardous chemicals and associated debris.

- Excessive transport distances or unavailability of adequate transport to haul debris from recovery sites to disposal site.

- Disposal of spilled oils which could be rerefined or otherwise treated to reduce the volume or neutralize any toxic effects.

- Inadequate control of debris-burning techniques and resulting objectionable emissions.

- Improper ultimate disposal methods for debris resulting in adverse impacts on surrounding land, water and air resources, and discontent among the local populace.

To date, the most common disposal solutions for recovered oil spill debris have been open burning near the recovery site, burial, landfilling with refuse, land cultivation, reprocessing, or incineration at a remote site. Some debris has been used e.g., oily sand has been incorporated in rosebeds). Other techniques, including innovative methods for treatment and disposal (including chemical treatment, biodegradation, and controlled incineration), must be investigated to provide the Coast Guard with additional disposal options.

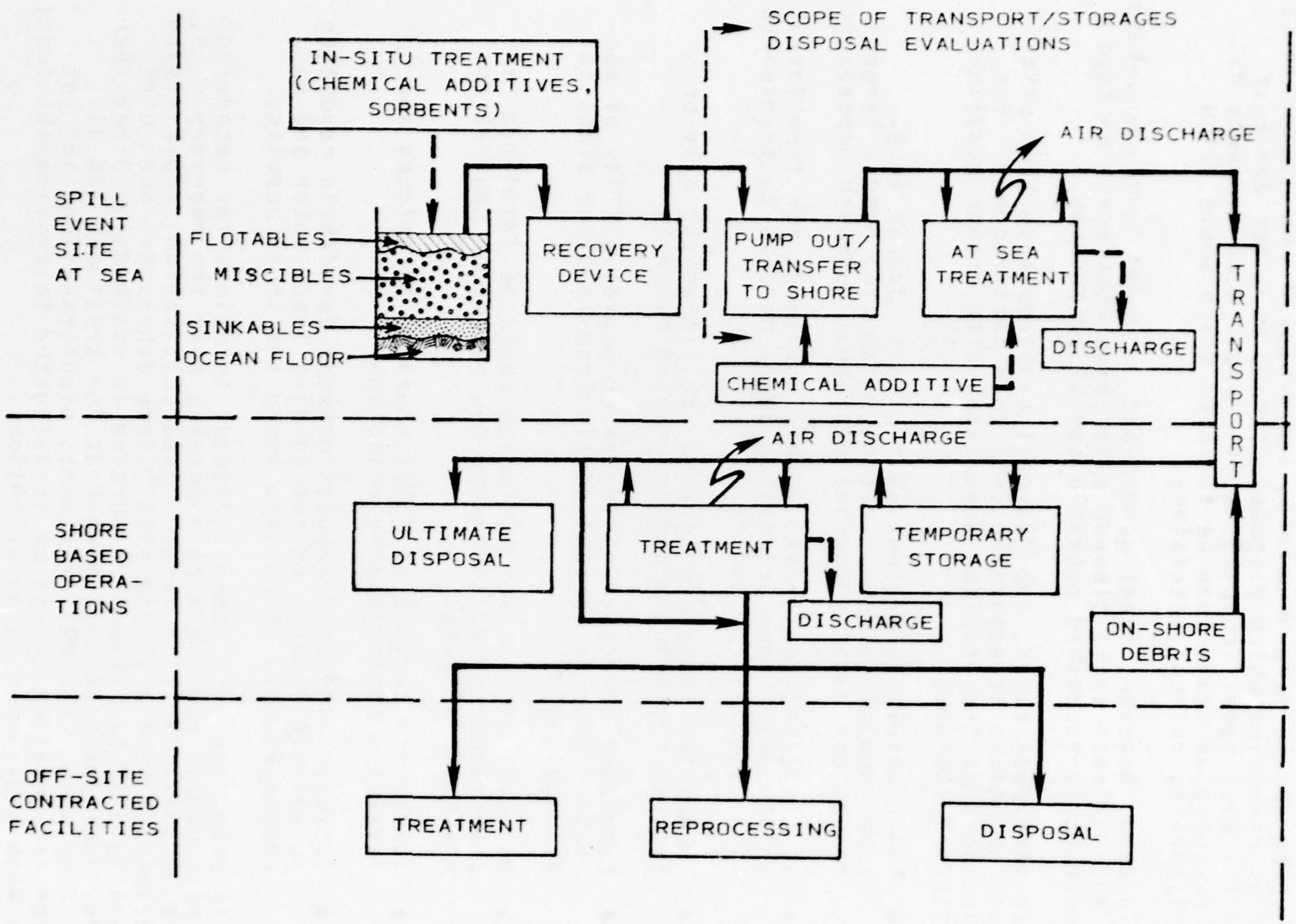

FIGURE 1. SPILL DEBRIS MANAGEMENT SCHEMATIC - SCOPE OF DEBRIS DISPOSAL PROJECT.

PROJECT OBJECTIVES

It is the intent of this U.S. Coast Guard-sponsored study to evaluate the engineering constraints and equipment requirements for handling and disposing of spilled oil and hazardous substances, associated solid material, and contaminated water recovered from spills in U.S. waters. All debris management facets are to be considered, including storage, transport, treatment, reprocessing, and disposal, as depicted in Figure 1.

Disposal hardware and processing systems are to be specifically identified and used to develop conceptual plans for transport/disposal options. The systems must address spills involving the chemicals listed in the Coast Guard CHRIS manuals (CG-466).

APPROACH

To accomplish these objectives, this project was conducted in a series of work tasks:

Task	Description
I	Describe Spill/Disposal Scenarios
II	Identify and Characterize Disposal Hardware Systems for Oils
III	Identify and Characterize Disposal Hardware Systems for Oils and Other Floating Chemicals
IV	Recommend Final Disposal Hardware Systems
V	Prepare System Management Development Plans
VI	Describe Disposal Techniques for Hazardous Chemicals

Specific objectives and corresponding approaches for each of these tasks are defined in terms of the overall project objectives.

Task I

The primary objectives of Task I are to 1) define the range of environmental conditions and spill debris characteristics which could be encountered during debris transportation and disposal operations; and 2) to combine the environmental and debris data into a cross-tabulation or matrix of all possible situations (called "debris disposal scenarios") for which disposal hardware systems or techniques will be designated.

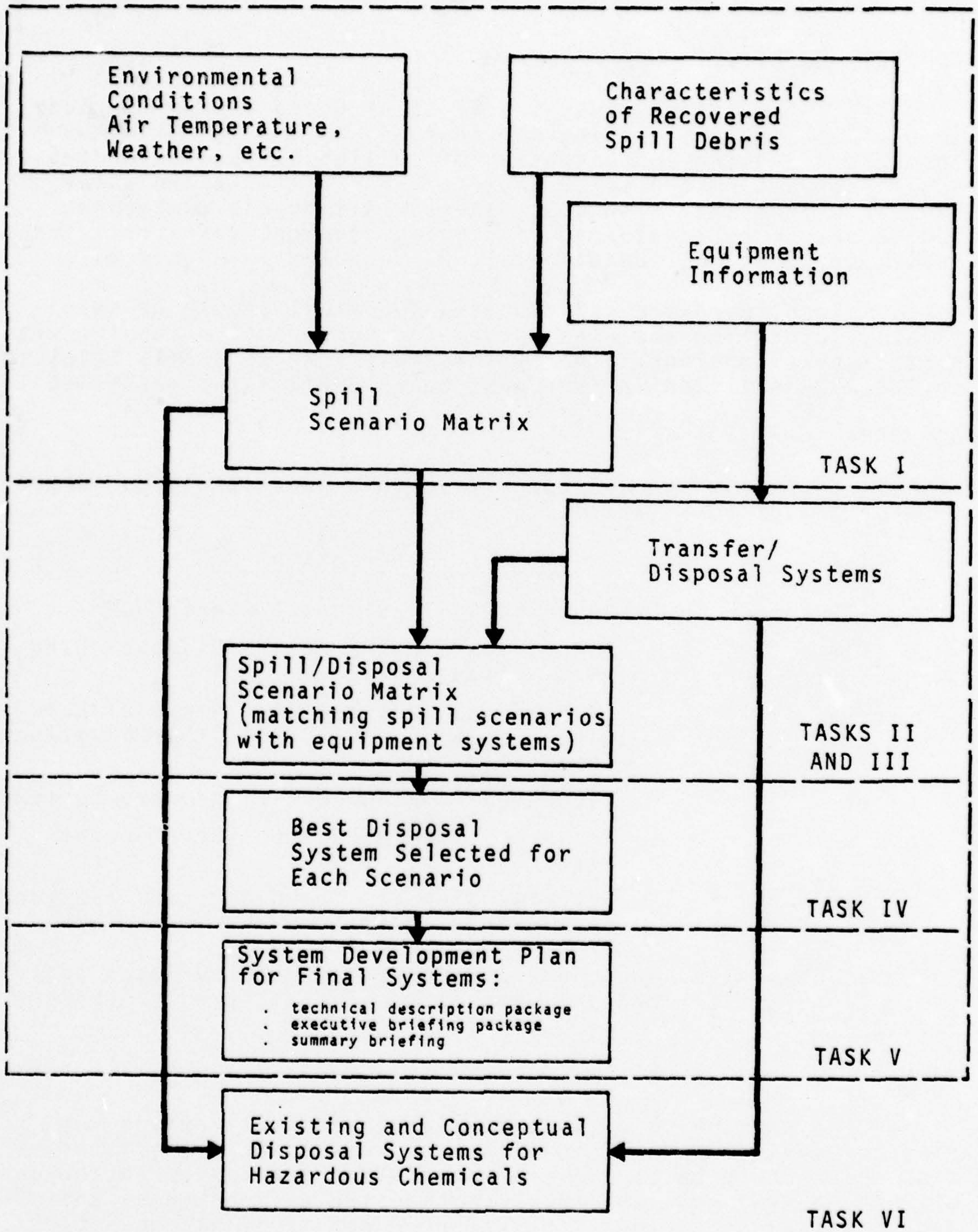

FIGURE 2. RELATIONSHIP OF INFORMATION BETWEEN PROJECT TASKS.

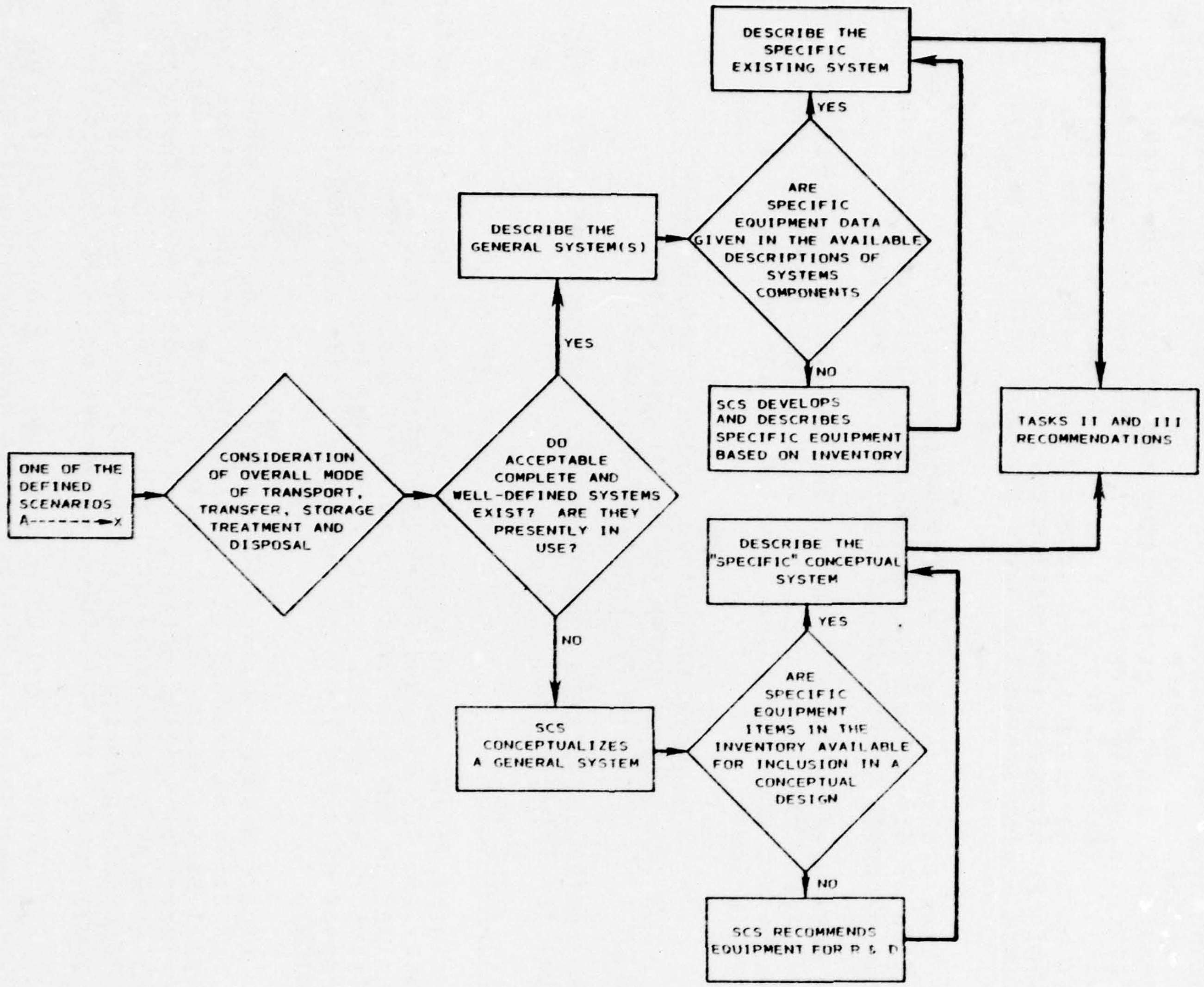

FIGURE 3. STEP EVALUATIONS FOR DERIVING EQUIPMENT SYSTEM ALTERNATIVES FOR EACH SCENARIO.

The scenarios of the Task I report are to indicate the range of offshore and onshore debris transportation disposal problems to be solved. The debris disposal scenarios are cross-referenced during subsequent tasks with specific disposal hardware systems to generate an overall debris disposal vs. applicable equipment matrix, as indicated schematically on Figure 2. The debris disposal scenario matrix presented here therefore provides a rational framework for the development and classification of hardware system concepts in Tasks II and III. The preliminary hardware information collected and categorized during Task I also provides a basis for work in Tasks II, III, and IV.

Task I also includes preliminary investigations and compilation of data concerning the hardware presently used for debris disposal operations,or that may be applied.

Data used in development of the tabulations and matrices was derived from interviews with knowledgeable persons from industry and government,and from literature reviews, as summarized below:

Private section contacts/interviews
Government contacts/interviews
Literature sources/reviewed

Also, numerous equipment manufacturers and suppliers were contacted for information.

Tasks II and III

Tasks II and III identify and describe hardware systems for 33 oils and 167 oils and floating chemicals, respectively, as described in the U.S. Coast Guard CHRIS manuals. The objectives of Tasks II and III are identical, except that one specifically addresses oils and the other addresses "oils and floating chemicals."

Figure 3 shows the overall process used during Tasks II and III for deriving disposal hardware systems for the various types of spill mass. Scenarios are defined based on expected characteristics of spilled material, environmental conditions, and types of debris associated with the spill mass. State-of-the-art information on spill mass disposal, existing disposal systems and subsystems, and individual equipment units is inventoried.

As a result of this work, a series of complete hardware systems comprised of individual units have been identified. Where acceptable, complete, and well-defined disposal systems exist and are presently in use, they are described in general terms, e.g., process steps. Otherwise, commercially manufactured systems that can be adapted for use are described. Where appropriate

equipment is not available, specific recommendations are made for research and development.

Task IV

Task IV includes further evaluations of the systems identified during Tasks II and III, based upon developed criteria. The one disposal system that most closely meets the criteria is selected for each scenario and recommended for procurement and/or further development.

Task V

The development plans derived during Task V are designed to facilitate Coast Guard development and procurement of equipment systems selected in Task IV. They provide preliminary recommendations as to how these equipment elements should be coordinated and packaged to provide complete and flexible debris handling and disposal systems. The plans include background, specifications and guidelines for equipment consideration, and system design.

The plans also provide summaries of each system's function, capabilities, compatibility with Coast Guard facilities and other technical considerations. A system development timetable and estimated development cost are derived, based on estimated present state of development of individual equipment and modification requirements for making equipment elements compatible.

Task VI

The objective of Task VI is to identify alternative techniques for disposal of hazardous chemicals, and to recommend those methods best suited to Coast Guard needs.

The approach to this task parallels the steps taken to define final disposal systems for oils and floating chemicals during the preceding tasks. Special storage, handling and disposal considerations are given to the hazardous nature of the 900 chemicals listed in the Coast Guard CHRIS Manuals.

SYSTEM COSTING METHODS

All disposal system costs are based upon individual costs for critical equipment elements and 10 percent of the total capital cost as a contingency for supportive hardware (e.g., hoses, electrical connections, plumbing).

The capital cost for each equipment item was provided by manufacturers or retailers in terms of 1978 dollars, and was based on F.O.B. at the respective manufacturer location. Annual operation and maintenance costs, salvage values, and equipment

lifetime were either provided by the manufacturer or estimated based on information for similar equipment. Estimates of operation and maintenance (O&M) costs include supplies, fuel, and power requirements, but do not include labor, except for clean-up of storage and handling equipment. Where estimated separately, fuel consumption is based on five incidents per year requiring 4 days (94 hr) of system operation. All other O&M cost estimates, as provided by equipment sources, are based on continuous usage.

The total life cycle cost for each disposal system is calculated as follows:

$$LCC = [TCC-SV_{20}] + [RCC_5-RSV_5] + [RCC_{10}-RSV_{10}]$$

$$+ [RCC_{15}-RSV_{15}] + [O\&M \times 8.514]$$

where

LCC = life cycle cost
TCC = total capital cost
SV_{20} = total system salvage value at end of lifetime (20 yr)
RCC_n = recurring capital costs at the year n
RSV_n = recurring salvage values at the year n
O&M = annual operational and maintenance costs (O&M x 8.514 = Total Annual Cost corrected to present value)

For simplicity and purposes of comparison, the following assumptions are employed:

- All systems are to be maintained for 20 yr (longest lifetime reported for critical equipment elements).
- All other equipment not lasting 20 yr must be replaced at the end of its lifetime for a recurring capital cost and associated salvage value.
- All costs, including annual O&M costs, are expressed as equivalent (1978) values to be summed and expressed as the life cycle cost. This is accomplished by multiplying the annual O&M costs by the appropriate 10 percent compound interest factor calculated as follows:

$$1978 \text{ value} = (\text{annual O\&M costs}) \frac{[(1+i)^n-1]}{[i(1+i)^n]}$$

where

i = 10%/yr
n = 20 yr
hence, 1978 value = (annual O&M costs) (8.514)

Total annual cost for each disposal system is equivalent to the annual operational and maintenance costs corrected to present value based on 10 percent interest factor over 20 yr.

All costs cited herein were provided by manufacturers or retailers once they were advised of the goals and purposes of this study. Prices were provided for system comparison purposes only, and do not in any way bind the manufacturers to provide the cited equipment at the costs given in this report.

II. SPILL AND DEBRIS DISPOSAL SCENARIOS

The primary objective of this section is to define a limited number of concise scenarios for which disposal hardware systems will be designated. These scenarios represent combinations of environmental conditions (weather and air temperature), spilled components (oils or chemicals), and debris characteristics.

ENVIRONMENTAL CONDITIONS

Figure 4 provides a description of the resulting twenty-four scenarios considered in this report. The primary environmental descriptors, weather conditions and air temperature, were found to be the most significant in determining the characteristics and quantity of recovered spill mass. Other more specific descriptors, such as wind, precipitation, and sea state, may have provided more scenario detail; yet their inclusion would have greatly increased the number of permutations and resultant scenarios. In addition, most of these descriptors were found to be at least partially dependent upon overall weather conditions (e.g., calm versus stormy).

In order to emphasize "worst-case" and "most-typical" situations, calm weather was grouped with warm air temperature and stormy weather was grouped with cold air temperature (less than 0°C).

Although air and water temperature are both important parameters in describing the environmental conditions for oil spill containment and recovery activities, only air temperature is necessary for spill/disposal scenarios. Since it is assumed that the functions of the disposal hardware systems commence at the points of discharge for the recovery devices (see Figure 1), water temperature should not significantly affect subsequent handling or disposal methods. Air temperature, on the other hand, directly influences the vapor pressure of the oil or chemical portion of the spill debris. Increased amounts of vapors emanating from warmed volatile or toxic materials may result in an immediate explosion or health hazard, or could affect pump efficiency. Handling of such materials in a warm environment may require special containers, transfer equipment, or other hardware to bring them safely to the disposal or recovery site.

Scenario	Operational Conditions*	Spilled Component/ Statement of Work Appendix	Debris Materials
A	C-W	Oils/A-2	No Debris (Dispersed in Water) (may be stored or transferred as a fluid)
B	S-C		
C	C-W	Oils and Floating Chem./A-3	
D	S-C		
E	C-W	Hazardous Chemicals/A-4	
F	S-C		
G	C-W	Oils/A-2	Heavy Sludge Soils, Sand, Sediments, Inorganic Sorbents (small amts. lifted by 1 man)
H	S-C		
I	C-W	Oils and Floating Chem./A-3	
J	S-C		
K	C-W	Hazardous Chemicals/A-4	
L	S-C		
M	C-W	Oils/A-2	Seaweed Flotsam Storm debris Organic Sorbents (small amts. lifted by 1 man)
N	S-C		
O	C-W	Oils and Floating Chem./A-3	
P	S-C		
Q	C-W	Hazardous Chemicals/A-4	
R	S-C		
S	C-W	Oils/A-2	primarily Large, Soaked Solids (pieces of dock, vessels, trees, etc. - requires special machinery for lifting)
T	S-C		
U	C-W	Oils and Floating Chem./A-3	
V	S-C		
W	C-W	Hazardous Chemicals/A-4	
X	S-C		

*C-W= calm and warm ($>0^{\circ}C$)
S-C= stormy and cold ($<0^{\circ}C$)

Figure 4. Spill scenario matrix.

Precipitation, as represented by "stormy" conditions, will affect many types of debris disposal activities, particularly incineration and some land disposal methods. Precipitation reduces visibility, a possible hindrance to safe transfer of debris from sea to shore. The potential for using aircraft to transport disposal hardware system components is reduced. Also, roads may become impassible during heavy rains. Spills often occur during (and because of) inclement weather, so debris management technology must be designed to operate under such conditions.

The scope of the debris handling considerations for this project assumes that the fluids and/or solid materials have been collected into some type of identifiable volume by primary recovery efforts (Figure 1). Therefore, the location of the spill occurrence is of secondary importance in determining the type or quantity of solid debris, and of the degree of emulsification encountered in fluids during the handling/disposal operations. A more important factor in equipment selection is the type of shoreline where initial debris handling/transfer operations are conducted. For example, access to municipal beaches in the vicinity of paved highways may be gained by a variety of vehicles and equipment not readily brought into remote shoreline areas. While the location factor is not directly represented by the various scenarios shown in Figure 4, it did represent an important criterion in system development and final system selection as described in Section V.

SPILLED COMPONENT

The oil, hazardous chemical, or mixture which was originally discharged during the spill incident usually has some potential for adverse environmental or health impacts, and is therefore the subject of the containment/recovery operations. It is assumed that all water and solids collected during spill recovery operations, and subsequently routed to the debris disposal system, contain at least traces of the spilled substance.

After spilling into the environment, the oil or hazardous substance may undergo significant alteration prior to recovery and transport. Weathering of oils, for instance, results in the escape of lighter molecular weight (more volatile) fractions into the atmosphere. In the open ocean, heavier oils may agglomerate and, if heavier than water, sink away from the spill mass. Biological and photochemical degradation of oils and chemicals can also change the composition and density of the original spilled components.

Prior to recovery, the spilled component may also become associated with water or any solids present at the spill site. Emulsification or dissolution of oils and chemicals into water has already been described. The spilled materials may also adsorb onto solid materials, such as wood or aquatic plants, resulting in a complex spill debris mixture.

In terms of spill debris management, the spilled component may impart certain physical or chemical characteristics to the debris which will significantly control the spill disposal system design. Physical characteristics include density, viscosity and volatility, as well as surface tension at the hydrocarbon/water interface; chemical characteristics include flammability, corrosiveness and solubility. For example, special equipment may be required to handle corrosive chemicals recovered from spills. The spilled component may also demonstrate toxicological or etiological characteristics which would make it dangerous for cleanup-disposal personnel to handle, store, or dispose of by conventional means.

Figure 5 shows how the spill mass characteristics have been defined by spilled component, debris materials, and environmental conditions. Three categories define the spilled component:

1. Oils
2. Oils and floating chemicals
3. Hazardous chemicals.

Specific groups of oils and/or chemicals included in each of these categories are listed in Appendices A, B, and C. By defining the spilled component in this manner, the spill debris scenarios are allocated to Tasks II, III and VI as follows:

Category	Report Section	Applicable Scenarios (See Figure 4)
Oils	III	A, B, G, H, M, N, S, T
Oils and floating chemicals	IV	C, D, I, J, O, P, U, V
Hazardous chemicals	VII	E, F, K, L, Q, R, W, X

Oils

Appendix A defined five groups for the 33 oils described in the CHRIS Manual (59). Divisions between groups are based on density, viscosity, volatility, combustibility, and toxicity. JP-4 is the most flammable and hazardous of the low-viscosity oils. Aromatic coal-tar is the most hazardous of the high-viscosity materials. Both of these unique oils were allocated to seperate groups (Groups IV and V), based on their hazardous and flammable nature. The other three groups include:

- Group I: remaining jet fuels, light fuel oils, and kerosene

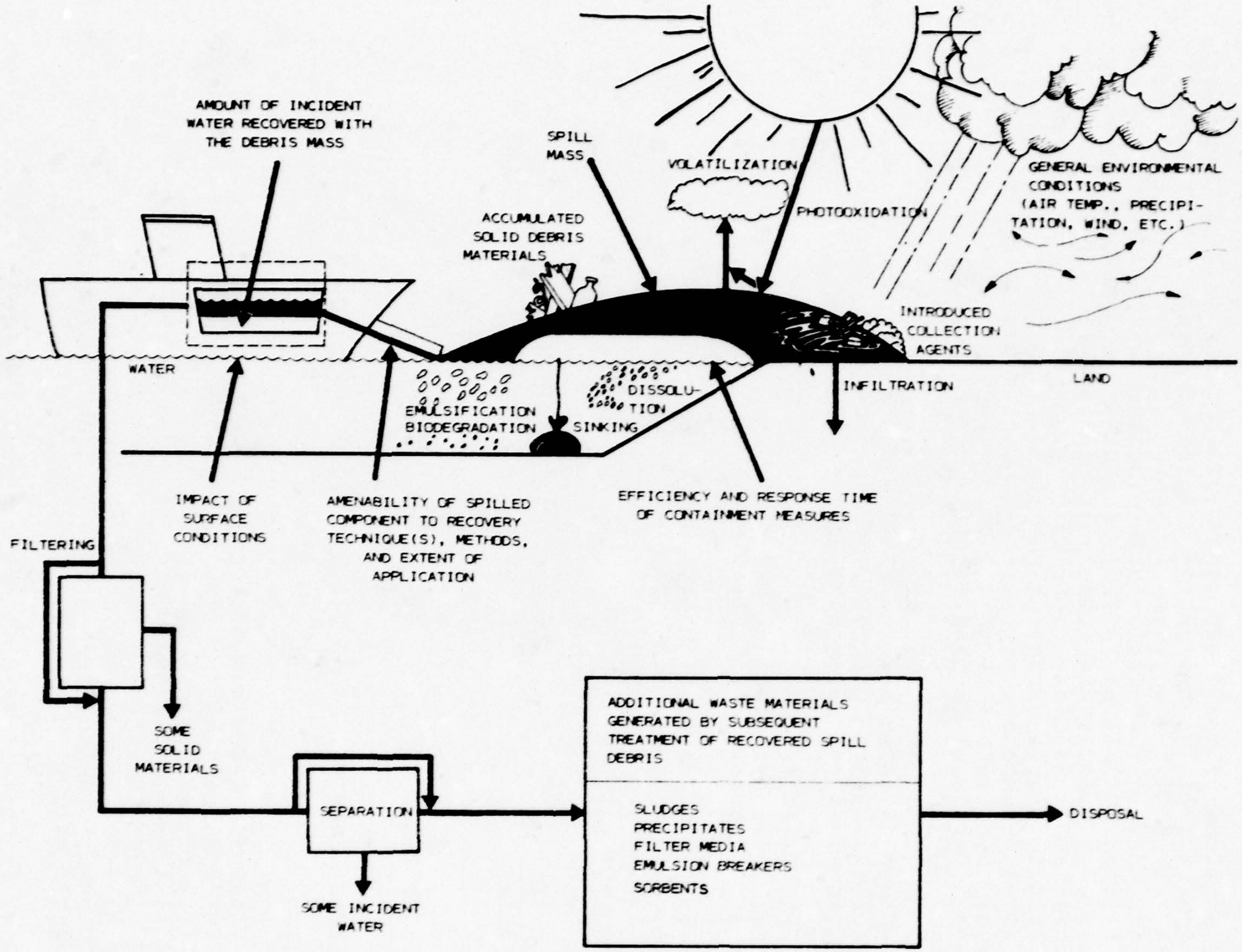

Figure 5. Factors influencing the volume and properties of spill debris.

• Group II: mid-density, high flash point oils including the heavier fuel oils and lubricating oils

• Group III: high-viscosity materials including heavy crudes, and Nos. 4, 5, and 6 fuel oils.

Oils and Floating Chemicals

Appendix B defines six groups for 167 oils and floating chemicals (Table 1). In this case, materials are divided according to solubility in water (above or below 0.01 lb/100 lb of water at 60° to 70°F), volatility, toxicity, and the tendency to solidify at low temperature.

Solubility was determined to be an important factor in ascertaining the need for further treatment of water previously in contact with the spilled component. Volatility and toxicity are key considerations for selecting disposal equipment which protects personnel from exposure or explosion. The tendency to solidify at low temperatures is also an important criterion for disposal system selection in those scenarios in which air temperatures are less than 0°C.

Hazardous Chemicals

Categorization of compounds on the list of hazardous chemicals (Appendix C) is based on physical parameters relevant to behavior in the aquatic environment and the toxic consequences to humans exposed to these by skin contact and/or inhalation.

Further categorization makes use of flash point as a measure of flammability (often correlated with volatility) of the chemical.

Use of all five properties: solubility, volatility, density, toxicity and causticity would theoretically require more than seventeen chemical groups, listed in Table 2. To avoid an unwieldy number of groups, certain properties are combined. For example, caustic sinkers are identified as a group containing only caustic toxic sinkers, while in other groups the property, causticity, is noted parenthetically.

Nine of the seventeen hazardous chemical groups are miscibles. As noted in Table 2, miscible substances are those whose solubility or metric solute/water ratio, taken at 25° ± 5°C greater than 1 percent. Alternatively, the chemical may react with water to form at least one soluble product. Considerations of temperature and salinity were not included in determination of miscibility.

TABLE 1. DEFINITION OF SIX GROUPS OF 167 OILS AND FLOATING CHEMICALS

IVF - Insoluble Volatile Floater:	Solubility below 0.01 lb/100 lb water at 60 to 70°F. Volatility indicated as a potential fire/explosion hazard by the CHRIS data. Flash point below 100°F.
INF - Insoluble Non-Volatile Floater:	Solubility below 0.01 lb/100 lb water at 60 to 70°F. Compounds are usually combustible, but not dangerously volatile.
SVF - Soluble Volatile Floater:	Compound exhibits some significant solubility in the water phase which may require further treatment following removal of floatables. Flash point below 100°F. Potential fire or explosion hazard indicated by CHRIS data.
SNF - Soluble Non-Volatile Floater:	Significant solubility in the water phase. Compounds are usually combustible, but do not represent an explosion hazard under normal handling conditions.
TF - Toxic Floater: (Compounds included in this set may also appear in cther sets)	CHRIS data indicates requirements for special handling considerations due to toxic nature of the compound.
LTSF - Low Temperature "Solid" Floater:	Oils which become highly viscous at or near 0°C. Polymeric chemicals which become brittle at or near 0°C. Chemicals with freezing points at or near 0°C. All materials in this group present a need for special transfer equipment in scenarios exhibiting cold air temperatures.

TABLE 2. DEFINITION OF 17 GROUPS OF 900 HAZARDOUS CHEMICALS

S - Sinker	Specific gravity $\geq$ 1.00 at 25°C $\pm$ 5°.
VS - Volatile Sinker	Specific gravity $\geq$ 1.00 at 25°C $\pm$ 5°. Flash point (open cup or closed cup) $\leq$ 38°C (100°F).
TS - Toxic Sinker	Specific gravity $\geq$ 1.00 at 25°C $\pm$ 5°. Threshold limit value (TLV) equivalent to 100 ppm or less assigned, or other indications of mild to severe toxic or irritating effects on humans.
TVS - Toxic Volatile Sinker	Specific gravity $\geq$ 1.00 at 25°C $\pm$ 5°. TLV $\leq$ 100 ppm or other indications of mild to severe toxic or irritating effects. Flash point (O.C. or C.C.) $\leq$ 38°C (100°F).
TCS - Toxic Caustic Sinker	Specific gravity $\geq$ 1.00 at 25°C $\pm$ 5°. Corrosive towards common construction materials, generally metals. TLV $\leq$ 100 ppm or other indications of mild to severe toxic or irritating effects.
LTSS - Low Temperature Solid Sinker	Specific gravity $\geq$ 1.00 at 25°C $\pm$ 5°. Freezing point above 0°C (32°F).
M - Miscible	Solubility or miscibility greater than 1% (weight solute/weight water) in pure water at 25°C $\pm$ 5°, or chemical reacts with water to form at least one soluble product.
CM - Caustic Miscible	Soluble in or reactive with water (see Miscible). Corrosive towards common construction materials, generally metals.
VM - Volatile Miscible	Soluble in or reactive with water (see Miscible). Flash point (O.C. or C.C.) $\leq$ 38°C (100°F).
VCM - Volatile Caustic Miscible	Soluble in or reactive with water (see Miscible). Flash point (O.C. or C.C.) $\leq$ 38°C (100°F). Corrosive towards common construction materials, generally metals.
TM - Toxic Miscible	Soluble in or reactive with water (see Miscible). TLV $\leq$ 100 ppm or other indications of toxic or irritating effects.
TCM - Toxic Caustic Miscible	Soluble in or reactive with water (see Miscible). TLV $\leq$ 100 ppm or other indications of toxic or irritating effects. Corrosive towards common construction materials generally metals.
TVM - Toxic Volatile Miscible	Soluble in or reactive with water (see Miscible). TLV $\leq$ 100 ppm or other indications of toxic or irritating effects. Flash point (O.C. or C.C.) $\leq$ 38°C (100°F).
TVCM - Toxic Volatile Caustic Miscible	Soluble in or reactive with water (see Miscible). TLV $\leq$ 100 ppm or other indications of toxic or irritating effects. Flash point (O.C. or C.C.) $\leq$ 38°C (100°F). Corrosive towards common construction materials, generally metals.
LTSM - Low Temperature Solid Miscible	Soluble in or reactive with water (see Miscible). Freezing point above 0°C (32°F).
G - Gas	Boiling point below 25°C (77°F). Vapor specific gravity (air) below 1.50. Specific gravity (water) of shipping state, solid, liquid, or compressed gas, below 1.00. May be toxic or volatile, that is TLV $\leq$ 100 ppm or flash point $\leq$ 38°C (100°F), as indicated for each compound.
DG - Dense Gas	Boiling point below 25°C (77°F). Vapor specific gravity (air) $\geq$ 1.50 or specific gravity (water) of shipping state, solid, liquid, or compressed gas, $\geq$ 1.00. May be toxic or volatile, that is TLV $\leq$ 100 ppm or flash point $\leq$ 38°C (100°F), as indicated for each compound.

DEBRIS CHARACTERISTICS

The debris portion of the spill mass is described by four categories:

- Spilled component dispersed in water - no solid debris
- Spilled debris consisting mainly of heavy sludge, soil, sand, sediments, or inorganic sorbents
- Spilled component mixed with large amounts of organic solids (seaweed, storm debris, organic sorbents)
- Spilled debris consisting mainly of large, soaked solids (pieces of dock, refrigerators, vessels, trees, etc.).

Solid debris may be the major constituent of the spill mass (such as oil-impregnated straw) or a minor constituent (such as small amounts of storm debris collected along with fluids). Systems are presented in this report which are capable of dealing with wide variations in fluid and debris contents and qualities:

- Small Solids - Solid material mixed with the spilled component to an extent that it may inhibit transfer by conventional means applicable to the spilled component alone. Examples are pine needles, small sticks, granular sorbents, sediments, sludges.
- Medium Solids - Materials rendering the spill mass incapable of exhibiting fluid characteristics; yet easily handled in small quantities by one man. Examples include oil-soaked straw, seaweed, sorbent pads, grasses, etc.
  - Grindable or Non-grindable: Handling of medium solids may be greatly simplified in certain instances by on-site grinding or mulching. Grindables would include flotsam or medium-sized wood. Non-grindables include rocks, metals, etc.
- Large Solids - Single objects requiring powered equipment for removal, i.e., cannot be handled by one man. Examples include piling, pieces of vessels, large trees, logs, etc.

Small and medium solids are typical of scenarios G, H, I, J, K, L, M, N, O, P, Q, R; and large solids are typical of scenarios S, T, U, V, W, X (see Figure 4).

The potential for combustion/biodegradation of certain debris types is included in the twenty scenarios, i.e., debris consisting of intermediate sized organic solids such as seaweed, driftwood, or organic sorbents. Spill debris defined by Scenarios M, N, O, P, Q, R, are probably more amenable to combustion/biodegradation as

a disposal method than are debris types described in Scenarios G, H, I, J, K, L; or S, T, U, V, W, X. Non-toxic oils or other organic floating chemicals dispersed in water (Scenarios A, B, C, D) may also be treated using biological techniques. The debris materials groups listed above also provide an opportunity to exhibit equipment systems which must cope with both pumpable and nonpumpable debris. In Scenarios A, B, C, D, E, F, no solid debris materials are present and the debris is considered to be fluid under most conditions. In cases where colder temperatures or component viscosities render the liquid debris unpumpable by conventional means, then Scenarios A, B, C, D, E, F, would more closely resemble Scenarios G, H, I, J, K, L where the debris is likened to a heavy sludge.

SPILL MASS VOLUME

Spill mass volume is another important variable to be considered. In most circumstances, relatively simple changes in equipment systems or the addition of minor equipment will make the system applicable to small, medium, or large spills, as defined below:

Spills Size	Volume
Small	<38,000 ℓ (10,000 gal)
Medium	38,000 ℓ to 380,000 ℓ (100,000 gal)
Large	>380,000 ℓ

Each disposal system is discussed in terms of its volume-handling capacities; the relative amounts of water and/or debris associated with the originally spilled material is also considered. Two general categories of spill material/water mixtures are identified:

- Oil or chemicals present in sufficient amounts to be separated from the water by gravimetric means (roughly more than 100 ppm)
- Oil or chemicals dissolved or as a colloid in water in small concentrations, such that the water must be specially treated prior to discharge to a receiving natural water body.

The latter condition will exist when the material is an emulsion with the water or is dissolved in the water. Concentration of spilled material is usually described in terms of ppm of material in the water. The former fluid type includes oils or chemicals contaminated with incindental water.

Spills of hazardous substances discussed in Section VII are assumed to be small (e.g., <38,000 ℓ). Spill mass volume is a characteristic which is best considered in developing the equipment systems and the related performance criteria in Section V of this report. The criteria ranks the capability of the particular system to respond to small volumes, large volumes or both. Sufficient equipment system types are described or devised for such a ranking within each of the twenty-four scenarios.

Practically all literature and interview accounts of oil spill incidents and spill mass scenarios have confirmed the validity of the twenty-four scenarios shown in Figure 4. Two approaches were taken to compare such data with the scenarios: where specific descriptions of recovered spill mass characteristics, handling, and subsequent disposal was not available, engineering expertise was used to suggest (based on the spilled component, location, and other factors) the most probable configuration; in oil spill accounts where specific spill mass descriptions were available, they were compared directly to the scenarios. Table 3 lists the twenty-four scenarios diagrammed in Figure 4. Table 4 briefly describes example spill events applicable to some of the derived scenarios.

TABLE 3. SCENARIO DESCRIPTIONS

Scenario Designation	Scenario Description	Scenario Designation	Scenario Description
A	Oil dispersed in water, no solid debris, calm weather, warm air temperature.	L	Hazardous chemical mainly consisting of heavy sludge, or mixed with soil, sand, sediments, inorganic sorbents, stormy weather, cold air temperature.
B	Oil dispersed in water, no solid debris, stormy weather, cold air temperature.	M	Oil mixed with large amounts of organic solids (seaweed, storm debris, organic sorbents), calm weather, warm air temperature.
C	Oil or floating chemical dispersed in water, no solid debris, calm weather, warm air temperature.	N	Oil mixed with large amounts of organic solids (seaweed, storm debris, organic sorbents), stormy weather, cold air temperature.
D	Oil or floating chemical dispersed in water, no solid debris, stormy weather, cold air temperature.	O	Oil or floating chemical mixed with large amounts of organic solids (seaweed, storm debris, organic sorbents), calm weather, warm air temperature.
E	Hazardous chemical dispersed in water, no solid debris, calm weather, warm air temperature.	P	Oil or floating chemical mixed with large amounts of organic solids (seaweed, storm debris, organic sorbents), stormy weather, cold air temperature.
F	Hazardous chemical dispersed in water, no solid debris, stormy weather, cold air temperature.	Q	Hazardous chemical mixed with large amounts of organic solids (seaweed, storm debris, organic sorbents), calm weather, warm air temperature.
G	Oil mainly consisting of heavy sludge, or mixed with soil, sand, sediments, inorganic sorbents, calm weather, warm air temperature.	R	Hazardous chemical mixed with large amounts of organic solids (seaweed, storm debris, organic sorbents), stormy weather, cold air temperature.
H	Oil mainly consisting of heavy sludge or mixed with soil, sand, sediments, inorganic sorbents, stormy weather, cold air temperature.	S	Oil primarily soaking large solids (pieces of dock, vessels, trees, etc.), calm weather, warm air temperature.
I	Oil or floating chemical mainly consisting of heavy sludge, or mixed with soil, sand, sediments, inorganic sorbents, calm weather, warm air temperature.	T	Oil primarily soaking large solids, stormy weather, cold air temperature.
J	Oil or floating chemical mainly consisting of heavy sludge, or mixed with soil, sand, sediments, inorganic sorbents, stormy weather, cold air temperature.	U	Oil or floating chemical, primarily soaking large solids (pieces of dock, vessels, trees, etc.), calm weather, warm air temperature.
K	Hazardous chemical mainly consisting of heavy sludge, or mixed with soil, sand, sediments, inorganic sorbents, calm weather, warm air temperature.		

TABLE 3 (continued)

Scenario Designation	Scenario Description
V	Oil or floating chemical primarily soaking large solids (pieces of dock, vessels, trees, etc.), stormy weather, cold air temperature.
W	Hazardous chemical, primarily soaking large solids (pieces of dock, vessels, trees, etc.), calm weather, warm air temperature.
X	Hazardous chemical primarily soaking large solids (pieces of dock, vessels, trees, etc.), stormy weather, cold air temperature.

TABLE 4. SPECIFIC SPILL EVENTS TYPIFIED BY THE SPILL DEBRIS SCENARIOS

Actual Spill Situation(s)	Scenario Designation
"... A crew from Burlington-Northern railroad responded to the spill on the evening of November 26 and constructed a straw filter fence about 150 ft downstream of the U.S. 87-89 bridge. The (number 6) fuel oil extinguished itself by the time it reached the bridge." - Weather was calm, but freezing temperatures were present.	N
"Western Environmental Services of Portland, Oregon (a clean-up contractor) was hired on November 27 to remove the (number 6) oil remaining in the partially ruptured tanker cars..." (freezing temperatures).	B
"Oil in the drainage ditch had contaminated the soil requiring the soil to be removed. A drag line with a clam shell scooped out the oily dirt and placed it in dump trucks for haul to the landfill. A total of 243 truckloads for a total of 2000 yards of oil soaked dirt was removed from the ditch."	G
"After securing the ruptured pipeline to Tank No. 63, the situation was evaluated for pollution impacts. It was then deemed necessary to remove several hundred pounds of sand and gravel soaked by the JP-4 by placing it in specially lined drums."	G
"During high winds and stormy weather, several 55-gallon drums containing kerosene were knocked over and ruptured. Approximately 250 gallons of contaminated spilled fluids mixed with rainwater were contained within the bermed storage area and later retrieved into a large waste-oil tank."	D
"Following the tanker explosion in the Long Beach Harbor, larger pieces of oil-soaked vessel and piling were stock-piled on the wharf."	S
"Tetraethyl lead sludges mixed with bottom sediments were dredged into open barges and then transferred into special vacuum trucks for transport."	K

III. SPILL DISPOSAL EQUIPMENT SYSTEMS FOR OILS

SCENARIO A - OIL ONLY, NO DEBRIS, CALM WEATHER, WARM AIR TEMPERATURE

Scenario A is defined as follows:

> Oil dispersed in water, no solid debris, calm weather, warm air temperature.

Oils to be included and considered under Scenario A include the five groups as defined in Appendix A. Environmental conditions include a moderate air temperature (from 15 to 25°C). Typical oil-water emulsions are about 50 percent oil and 50 percent water, although this can vary over a wide range.

Figure 6 shows the general system options for receiving fluids from primary recovery craft and transporting the fluids to off-site facilities, or to on-site treatment or disposal facilities. Options are indicated for shipboard storage or in-water storage vessels and brought to shore. On-board storage tanks are off loaded to trucks or pumped out along with towable in-water craft. Pumped-out fluids are processed or disposed of on site, or are transferred to a tank truck for transport to contract disposal facilities. Appendix G explains in detail the options for disposal by a third party disposal company.

System 1

System 1 is defined as follows (Figure 7):

> Pumpout of primary recovery vessel (PRV) or transfer from other on-site processing by either a positive displacement pump or a centrifugal pump mounted on a workboat. Optional demulsification and/or oil/water separation is conducted on board. The separated spill component is then transferred to on-board storage and burned in a sea-going incinerator.

Critical equipment elements of the system are shown in Table 5. The total system life cycle cost for an estimated 20-year life is $875,854, and the system's annual cost is $21,700.

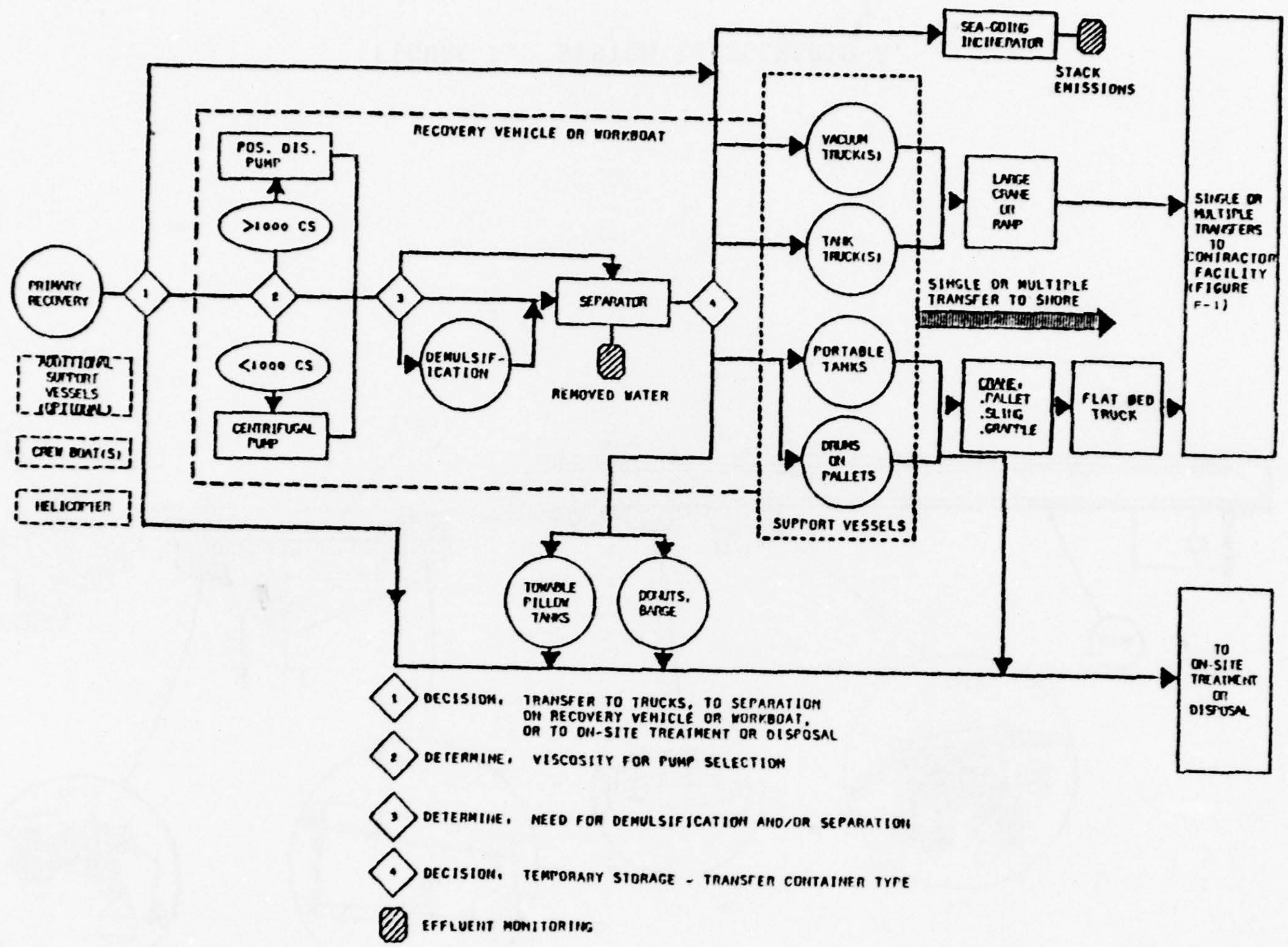

FIGURE 6. SCENARIOS A THROUGH F: GENERAL EXISTING SYSTEMS FOR STORAGE, TRANSFER, AND TRANSPORT OF RECOVERED SPILL MASSES.

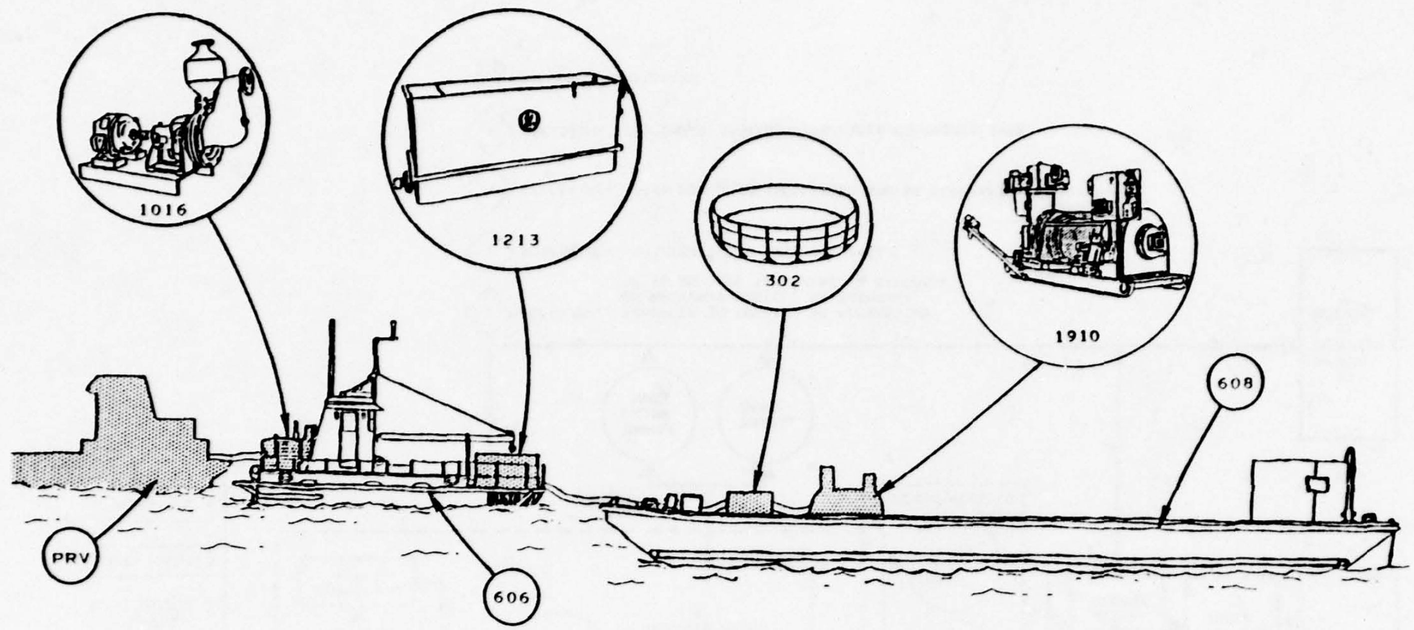

FIGURE 7. SYSTEM 1, SCENARIO A.

TABLE 5. SYSTEM 1: CRITICAL EQUIPMENT ELEMENTS.

Qty	Equipment Element	Item No.*	Estimated Life (Yr)	Capital Cost (1978 $)	Approximate Annual O&M Costs ($)	Estimated Salvage Value ($)
1	workboat	606	20	80,000	5,600	4,000
1	barge	608	20	150,000	5,000	8,000
2	centrifugal pump and 10 hp motor	1016	10	12,600 (6,300)†	600	120
2	oil/water separator	1213	20	27,800 (13,900)†	3,000	1,400
5	temp. storage tank	1302	20	15,000 (3,000)†	1,500	800
1	incinerator	1910	10	190,000	6,000	10,000
	contingency (10%)	--	--	47,540	--	--

Life Cycle Cost = $ 875,854
Total Annual Cost = $ 21,700

*See Appendix D.
†Unit costs.

A two-day transfer time is considered to be a realistic objective for this system,* with pump(s) on a 5 hr/day duty cycle.

The required flow rate for the pump(s) is shown below:

$$Q = \frac{v}{t} = \frac{\text{Spill Mass Volume}}{2\ (5\ \text{hr})\ (60\ \text{min/hr})} = 133\ \text{gal/min}$$

A typical self-priming centrifugal pump (Worthington 2 in CNGK-84) with 2-in inlet and outlet, using 45 ft or 2-in suction hose and 150 ft of 2-in discharge hose, can deliver 140 gal/min for a total head of 70 ft and requires a 7.5 hp motor.

Each such pump and motor plus frame weighs about 184 kg (400 lb) and will occupy a space roughly 1.5 m long by 0.45 m wide by 0.6 m high (5 ft x 1 1/2 ft x 2 ft).

Although one pump is capable of meeting the recovery operation requirements, it is recommended that two be allocated for the following reasons:

- As a standby unit in case of malfunction
- For additional transfer capacity to auxiliary workboat
- For transfer of separated oil from temporary storage tank(s) to tank truck.

A typical recovery vessel, the M/V Port Service (used in Boston Harbor), has a waterline length of over 13.7 m (38 1/2 ft) and a beam of 5 m (16 ft). Two oil/water separators can be positioned on the usable deck space (about 5 m by 4 m). Reduction in freeboard by the two oil/water separators, fully loaded with liquid spill mass, is on the order of 0.1 m (about 3 1/2 in).

There is also ample space on the deck of a support barge to accommodate both separators, should location aboard the recovery vessel be difficult. Each G.E. (P.S.I.)-Model OPL150 or equivalent unit weight 1,910 kg (4,200 lb) and occupies a space roughly 3.9 m long by 2.1 m wide by 1.5 m high (13 ft x 7 ft x 5 ft).

An optional practice during the spill-mass collection operation is demulsification by addition of chemical emulsion breaker. Demulsifiers may be added to recovered fluids in five open-top tanks located on the support barge (Figure 8).

Oils Which Can and Cannot Be Handled--

Oil groups II and III can be accommodated using System 1. Groups I, IV, and V are too flammable to enable safe on-board incineration.

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*262 m^3 in 2 days.

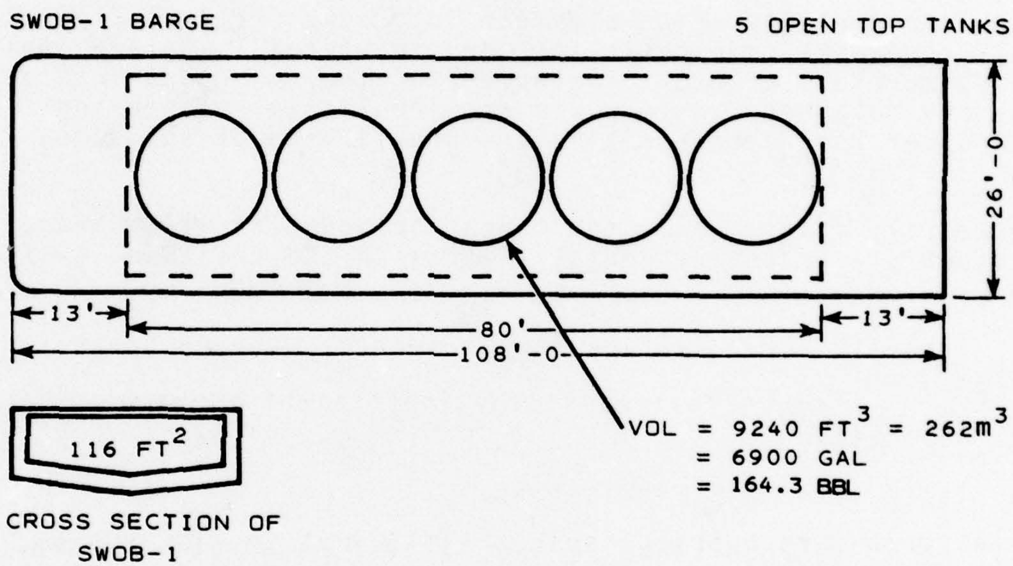

FIGURE 8. SYSTEM 1: OPEN TOP, FIELD ERECTABLE TANKS POSITIONED ON BARGE DECK.

Approximate Quantity of Spill Mass Which Can Be Handled--

The processing rate for System 1 is limited by the incinerator unit recommended. An incinerator (Metpro Model 16090) weighing about 18,000 kg (40,000 lb), occupying a space about 6.0 m x 7.1 m x 28 m (20 ft x 7 ft x 9 ft), consumes waste at the rate of roughly 600 kg/hr (1,320 lb/hr). A single such unit would require slightly over 10 days continuous burning in order to dispose of about 152,000 ℓ of waste. Actually, owing to its volatility, a significant quantity of the oils of Group I will have evaporated so that, for such a spill, the 10-day continuous incineration may be conservative.

Technical Feasibility of Development Including Critical Elements--

All equipment components included in System 1 are available on the commercial market. Development of the equipment into a Coast Guard response system would require little engineering expense other than proper sizing and acquisition of the components.

Environmental Impacts of System Operation and Mitigation Measures--

Potential for environmental impacts in the treatment system follow:

- Overfilling or leakage from temporary storage tanks
- Redischarge of oil caused by inefficient oil/water separation
- Incinerator stack emissions.

Overfilling of storage tanks during large-flow operations can be prevented by continuous monitoring of the fluid level in the tanks. Simple liquid level detection devices are available on the market which sound a warning alarm when a predesignated tank volume (fill height) is reached. The impact of leakage from tanks may be minimized by erecting temporary barriers around the perimeter of the tank, and by providing a supply of sorbent materials. Contingency plans should be prepared ahead of time for transferring the contents of a leaking storage tank to another holding facility. Directives for proper maintenance and operation of oily waste storage facilities are included in the Environmental Protection Agency's regulations for Spill Prevention Control and Countermeasures (40 CFR, Part 112).

The redischarge of oil with aqueous oil/water separator effluents can be minimized by carefully monitoring the oil content in the stream. If the oil content is too high for discharge of the fluids back to the watercourse, as defined by water quality standards, then the fluids may have to be treated further (see System OS-2 under "On-Site Treatment"). Another mitigating measure which can be taken is to reduce the flow rate through the separator, thereby increasing the retention time and

allowing for more effective partitioning of the oil and water phases in the unit.

The variable quality of the incinerator emissions which may originate from this system precludes its use at shorelines in heavily populated or urbanized zones. In remote areas, the impact from off-shore incineration operations is secondary to the need for efficient and effective disposal of the spilled oil.

Approximate Size and Weight of the Equipment--

Table 6 shows the approximate dimensions and weights of each equipment element for System 1. Plans for each element are shown in the indicated figures.

TABLE 6. SYSTEM 1: DIMENSIONS AND WEIGHTS OF CRITICAL EQUIPMENT ELEMENTS

Equipment Element	Item No.	L(m)	W(m)	H(m)	D(m)	Weight (kg)	Fig.*
Workboat	606	11.73	5.03	1.60	-	13,750	E-15
Barge	608	32.31	7.92	2.59	-	90,710	E-16
Centrifugal pump†	1,016	1.50	0.45	0.60	-	184	E-21
Oil/water separator	1,213	3.86	2.08	1.50	-	1,910	E-22
Open top tanks (envelope)	302	1.2	3.0	0.3	-	885	E-2
Incinerator	1,910	5.96	2.11	2.81	2.11	17,920	E-31

*For conceptual drawing, see figure indicated, Appendix E.

†Worthington - 2-in CNGK-84, or equal.

Transportability by existing Coast Guard Vessels and Aircraft capability. See Appendix F.

Special requirements--Specially trained Coast Guard personnel are required for installation and operation of all equipment included in System 1. During simultaneous operation of all equipment elements, it is estimated that a maximum of six persons are required as crew (barge - 2, workboat - 1, pump - 1, oil/water separator - 1, incinerator - 1).

Diesel fuel must also be provided for operation of the pumps, crane system, and workboats. All units are provided with limited on-board fuel storage. For prolonged operations, a small tank truck may be required for bringing additional fuel to the site.

System 2

System 2 is defined as follows (Figure 9):

> Shipboard pumpout of primary recovery vessel (PRV) and the optional demulsification and/or oil/water separation of the spill-mass fluids are conducted in the same manner as described in System 1. Fluid is then transferred into vacuum tank-trailers present on the deck of a towed barge. In the transfer of the barge to shore, the tanks are towed ashore over a ramp. Trucks then deliver the tank-trailers and contents to on-site treatment or to an off-site facility.

Critical Elements of the system are shown in Table 7.

With each of 4 vacuum tanks located on the barge deck filled with liquid to 19,000 ℓ (5,000 gal) capacity, the barge freeboard is estimated to be reduced about 0.5 m (1 ft 8 in). Since the light barge freeboard is about 1.8 m (6 ft), no stability problem is anticipated. The total system life cycle cost and annual cost are $1,057,500 and $38,200, respectively.

Oils Which Can and Cannot Be Handled--
Some oils, particularly those in Group II (Appendix A), are highly viscous and, in high concentrations, may inhibit effective oil/water separation. Provisions for both a positive displacement and centrifugal-type pump in the system allow for efficient pumping capabilities over a wide range of viscosities. All other oil groups (I, II, and IV) can be processed by this handling system. Groups III and V, where oil/water separation is not feasible, may require direct transport of all of the fluid emulsion to shore disposal facilities.

Approximate Volume of Spill Mass Which Can Be Handled--
Despite care in recovery, the oil and water can become mixed into an emulsion containing up to 50 percent oil and 50 percent water. Thus, a total spill-mass volume of 303 m^3 (80,000 gal) needs to be moved towards ultimate disposal. This entire volume can be accommodated by the on-board storage facilities included in System 1.

Technical Feasibility of Development Including Critical Elements--
All equipment components included in System 2 are available on the commercial market. Development of the equipment into a mobile Coast Guard response system would require little engineering expense other than proper sizing and acquisition of the components.

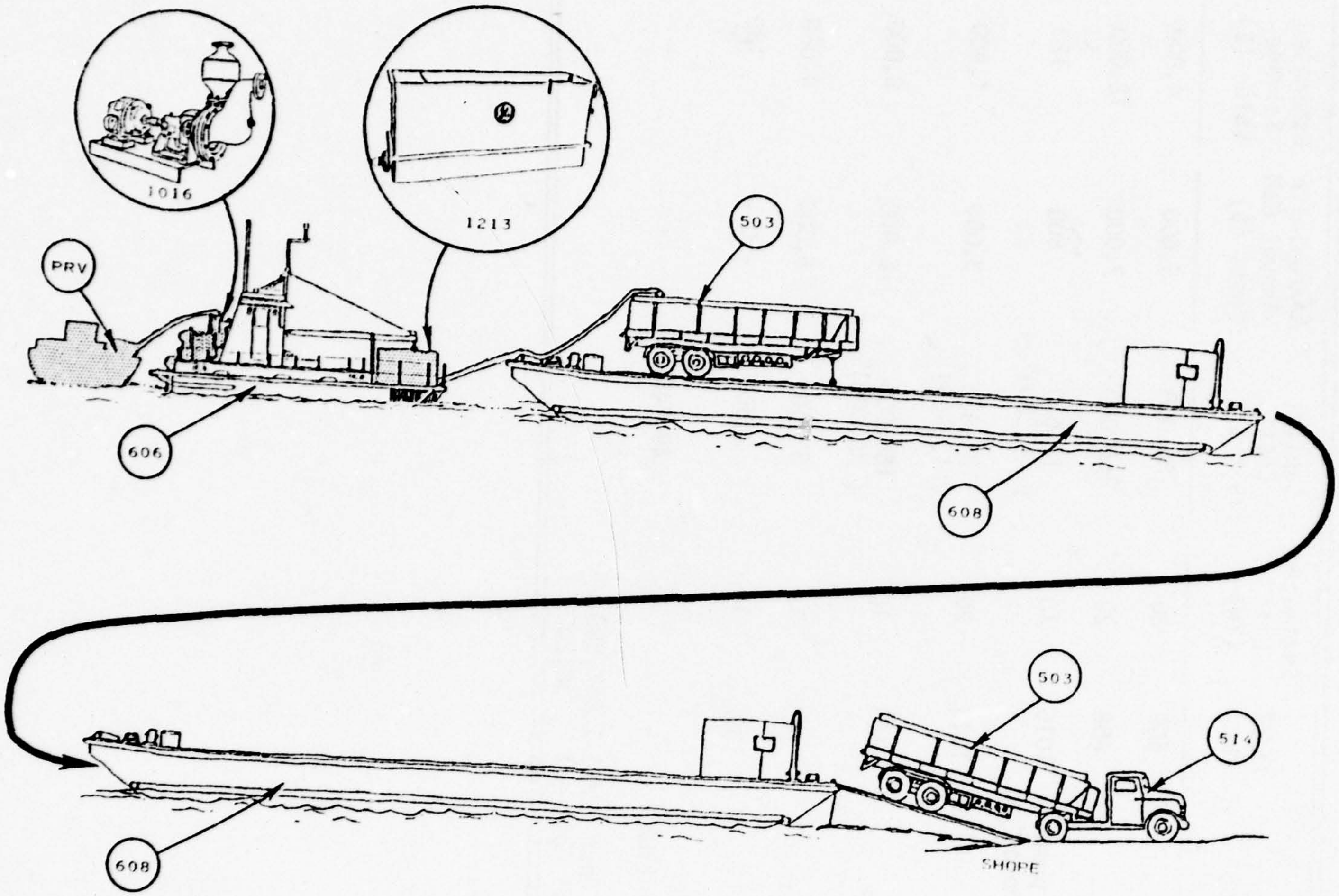

FIGURE 9 . SYSTEM 2, SCENARIO A.

TABLE 7. SYSTEM 2: CRITICAL EQUIPMENT ELEMENTS

Qty	Equipment Element	Item* No.	Estimated Life (Yr)	Capital Cost (1978 $)	Approximate Annual O&M Costs ($)	Estimated Salvage Value ($)
1	workboat	606	20	80,000	5,600	4,000
1	barge	608	20	150,000	7,000	12,000
2	centrifugal pump and 10 hp motor	1016	10	12,600 (6,300)†	600	120
2	oil/water separator	1213	20	27,800 (13,900)†	3,000	1,400
8	vacuum tanks	503	10	160,000 (20,000)†	16,000	8,000
1	truck-tractor	514	10	59,000	6,000	4,000
1	ramp	1302	10	2,000	- 0 -	100
	contingency (10%)	-	-	49,140	-	-
	Life Cycle Cost = $ 1,057,500					
	Total Annual Cost = $ 38,200					

*See Appendix D.
†Unit costs.

Environmental Impacts of System Operation and Mitigation Measures--

Potential for environmental impacts in the disposal system include the following:

- Accidental oily discharges during pumping out of recovery vessels or ship-to-shore transfer of oily wastes
- Accidental overfilling or leakage from on-board storage tanks
- Redischarge of oil caused by inefficient oil/water separation.

Accidental oily discharges during transfer operations can be contained by placing booms in the water around such operations. Sorbents are provided to retrieve small oil spills. Overfilling of storage tanks and inefficient oil/water separation can be avoided and controlled as described for System 1.

Approximate Size and Weight of the Equipment--

Table 8 shows the approximate dimensions and weights of each equipment element for System 2. Plans for each element are shown in the indicated figures.

Transportability by Existing Coast Guard Vessel and Aircraft Capability--

Appendix F describes the dimensions of various cargo holds for Coast Guard aircraft and vessels.

Transportability by Other Than Coast Guard Vessel and Aircraft--

See Appendix F.

Special Requirements--

The limiting elements in System 2 are the vacuum tank and truck, which cannot be transported to the field site by sea or air. These are, however, secondary to the processing operation, and are used only for transporting recovered oil to an on-site location or an off-site facility for treatment. Furthermore, vacuum trucks can often be leased locally.

Specially trained Coast Guard personnel are required for installation and operation of all equipment included in System 2. During simultaneous operation of all equipment elements, it is estimated that a maximum of five persons is required as crew (includes barge - 2, workboat - 1, pump - 1, oil/water separator - 1). Additional support transport may be required for transporting the crew to the field of operation.

Diesel fuel must also be provided for operation of the pumps and the workboat. These units are provided with limited on-board fuel storage. For prolonged operations, a small tank truck may be required for bringing additional fuel to the site.

TABLE 8. SYSTEM 2: DIMENSIONS AND WEIGHTS OF CRITICAL EQUIPMENT ELEMENTS

Equipment Element	Item No.	L (m)	W (m)	H (m)	D(m)	Weight (kg)	Figure*
Workboat	606	11.73	5.03	1.60	-	31,750	E-15
Barge	608	32.31	7.92	2.59	-	90,710	E-16
Centrifugal pump†	1016	1.50	0.45	0.60	-	184	E-21
Oil/water separator	1213	3.86	2.08	1.50	-	1,910	E-22
Vacuum tank	503	9.80	-	3.35	1.68	7,484	E-8
Ramp	2302	11.00	variable	1.52	-	2,268	
Truck-tractor	514	5.98	2.44	2.98		19,800	E-10

*For conceptual drawing, see figure number indicated, Appendix E.

†Worthington - 2-in CNGK-84, or equal.

System 3

System 3 is defined as follows (Figure 10):

> Shipboard pumpout of primary recovery vessel and the optimal demulsification and/or oil/water separation of the spill-mass fluids, are conducted in the same manner as described in System 1. Fluid is then transferred into waste oil tanks, or to drums on pallets located on the workboat deck or on an adjacent barge. Upon transfer of the work-boat or service barge to shore, fluid is lifted by means of a pallet crane onto shore for on-site treatment. Other-wise, the tanks or pallets are loaded onto a flatbed truck by a forklift and transferred to an off-site facility.

The critical elements of System 3 are shown in Table 9. The total system life cycle cost and annual cost are $964,911 and $37,220, respectively.

Certain transfer options present themselves if consideration is given to the use of a large number of portable rectangular containers. Typical capacities of rectangular tote tanks (Tote System Division, Hoover Ball and Bearing Co., Beatrice, Nebraska), are about 2 m^3 each. The advantage to these is that they are very easily off loaded by a pallet crane.

Oils That Can and Cannot Be Handled--

See System 2.

Approximate Volume of Spill Mass Which Can Be Handled--

For a 152 m^3 (40,000 gal) oil spill, 80 such containers would need to be carried on the deck of the workboat or barge. Each would need to be charged with oil recovered by oil/water separator. Ninety-six tanks in six rows of sixteen tanks each can be arranged on the deck of the barge such that about 0.23 m (9 in) of space between adjacent tanks is available for handling purposes.

Feasibility of Development Including Critical Elements--

All equipment components included in System 3 are available on the commercial market. Development of the equipment into a mobile Coast Guard response system would require little engineering expense other than proper sizing and acquisition of the components.

Environmental Impacts from System Operation and Mitigation Measures--

See System 2.

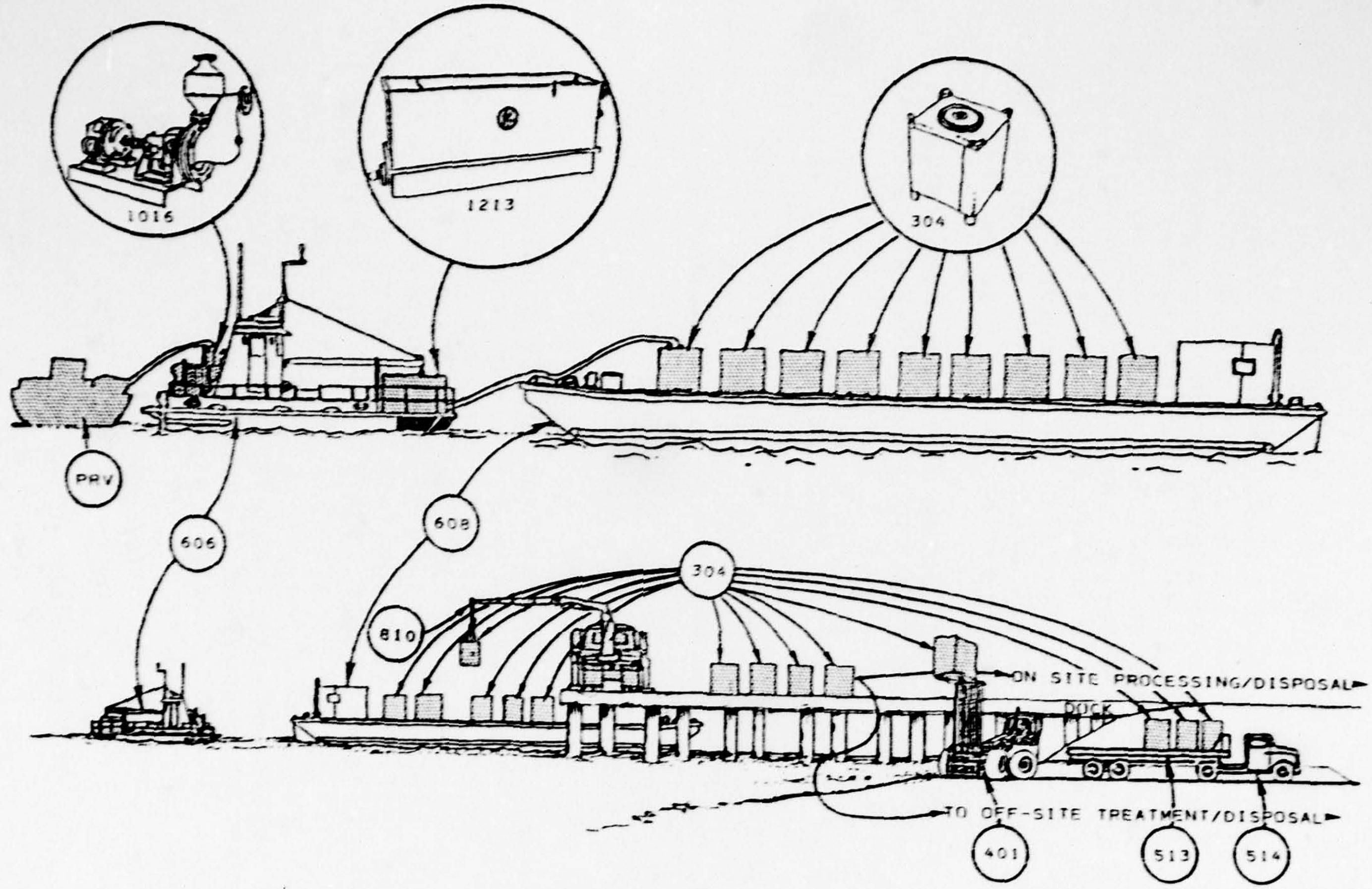

FIGURE 10. SYSTEM 3, SCENARIO A.

TABLE 9. SYSTEM 3: CRITICAL EQUIPMENT ELEMENTS

Qty	Equipment Element	Item* No.	Estimated Life (Yr)	Capital Cost (1978 $)	Approximate Annual O&M Costs ($)	Estimated Salvage Value ($)
1	workboat	606	20	80,000	5,600	4,000
1	barge	608	20	150,000	5,000	8,000
2	centrifugal pump and 10 hp motor	1016	10	12,600 (6,300)†	600	120
2	oil/water separator	1213	20	27,800 (13,900)†	3,000	1,400
80	portable tank	304	10	72,000 (900)†	13,000	3,000
1	crane	810	10	12,500	750	600
1	forklift	401	10	24,000	2,400	1,200
1	flatbed trailer	513	10	8,700	870	400
1	truck-tractor	514	10	59,000	6,000	4,000
	contingency (10%)	--	--	44,660	--	--

Life Cycle Cost = $964,911
Total Annual Cost = $37,220

*Appendix D.
†Unit costs.

Approximate Size and Weight of the Equipment--

Table 10 shows the approximate dimensions and weights of each equipment element for System 3. Plans for each element are shown in the indicated figures.

Transportability by Existing Coast Guard Vessel and Aircraft Capability--

Appendix F describes the dimensions of various cargo holds for Coast Guard aircraft and vessels, and the transportability of equipment included in System 3.

Transportability by Means Other Than Coast Guard Vessel and Aircraft--

See Appendix F.

Special Requirements--

The limiting elements in System 3 are the flatbed trailer 513 and truck 514, which cannot be transported to the field site by sea or air. These are secondary to the processing operation, however, and are used only for transport of fluids to an off-site facility.

Specially trained Coast Guard personnel are required for installation and operation of all equipment included in System 3. During simultaneous operation of all equipment elements, it is estimated that a maximum of six persons is required as crew (including barge - 2, workboat - 1, pumps - 1, oil/water separator - 1, fork-lift - 1). Additional support may be required for transporting the crew to the field of operation.

Diesel fuel must also be provided for operation of the pump, crane system, and workboat. These units are provided with limeted on-board fuel storage. For prolonged operations, a small tank truck may be required for bringing additional fuel to the site.

<u>System 4</u>

System 4 is defined as follows (Figure 11):

> Shipboard pumpout of the primary recovery vessel (PRV) and the optional on-board demulsification and/or oil/water separation of the spill-mass fluids, are conducted in the same manner as described in System 1. Fluid is then transferred into a towable pillow tank or donut towed by an additional workboat. The towable storage vessel is then transferred to shore and off loaded to on-site treatment or disposal.

The critical elements of System 4 are shown in Table 11. The estimated total life cycle and annual costs for System 4 are $1,060,847 and $26,200, respectively.

TABLE 10. SYSTEM 3: DIMENSIONS AND WEIGHTS OF CRITICAL EQUIPMENT ELEMENTS

Equipment Element	Item No.	L (m)	W (m)	H (m)	D	Weight (kg)	Figure*
Workboat	606	11.73	5.03	1.60	-	31,750	E-15
Barge	608	32.31	7.92	2.59	-	90,710	E-16
Centrifugal pump†	1016	1.50	0.45	0.60	-	184	E-21
Oil/water separator	1213	3.86	2.08	1.50	-	1,910	E-22
"Tote Tanks" tm	304	1.07	1.20	1.80	-	165	E-4
Crane	810	8.70#	-	10.00#	1.00	2,110	E-17
Forklift	401	4.57	2.26	3.76	-	4,540	E-32
Truck-flatbed trailer	513	13.0	2.64	1.20	-	4,590	E-9
Truck-tractor	514	5.98	2.44	2.98	-	19,800	E-10

*For conceptual drawing, see figure number indicated, Appendix E.

†Worthington - 2-in CNGK-84, or equal.

#Key dimensions: L = lateral reach, H = lift distance.

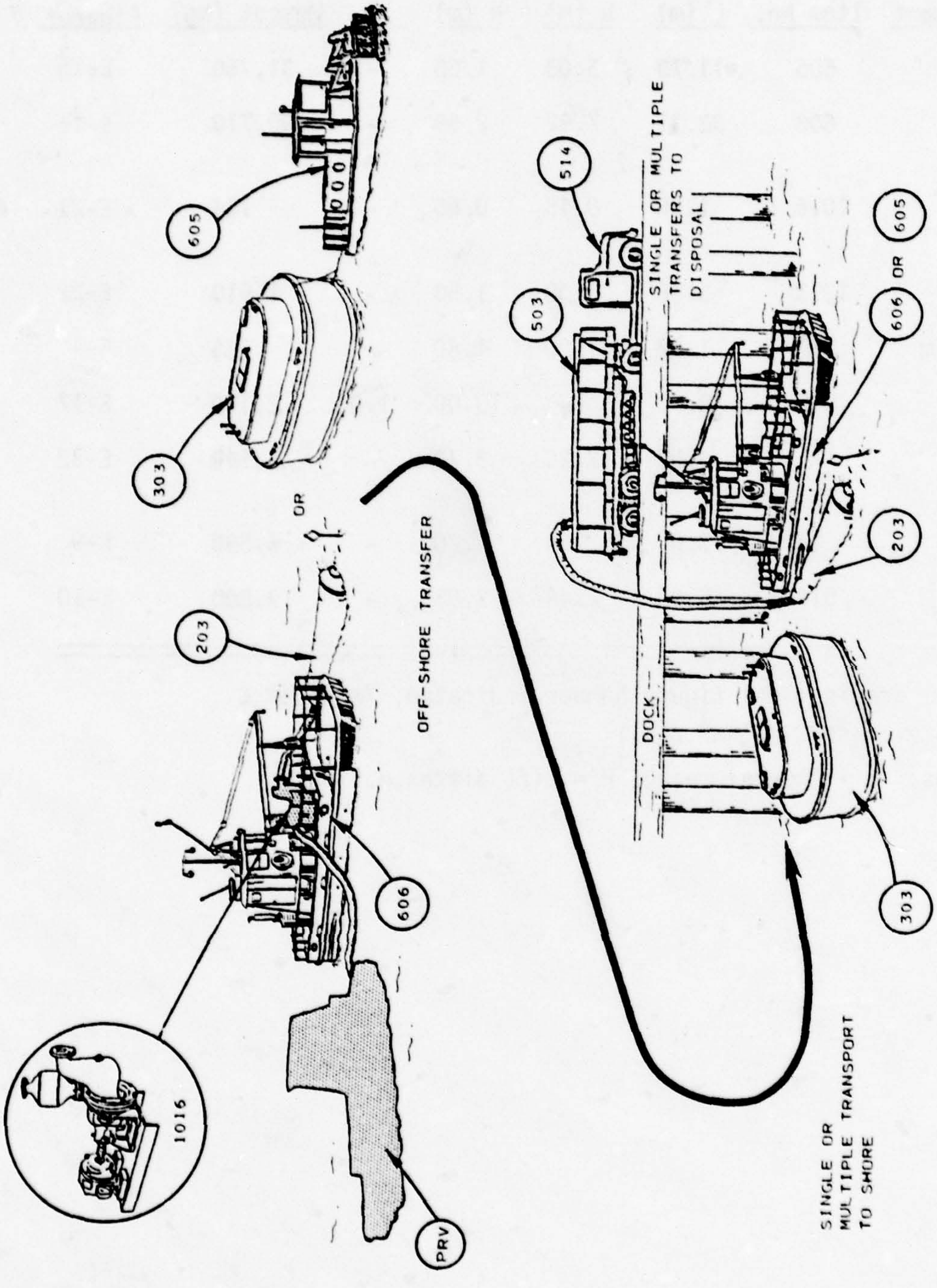

FIGURE 11. SYSTEM 4, SCENARIO A.

TABLE 11. SYSTEM 4: CRITICAL EQUIPMENT ELEMENTS

Qty	Equipment Element	Item* No.	Estimated Life (Yr)	Capital Cost (1978 $)	Approximate Annual O&M Costs ($)	Estimated Salvage Value ($)
1	workboat	606	20	80,000	5,000	4,000
3	centrifugal pump and 10 hp motor	1016	10	18,900 (6,300)†	900	180
2	towable pillow tank	203	5	98,000 (49,000)†	6,300	- 0 -
1	donut	303	10	65,000	4,000	3,000
1	small workboat	605	20	25,000	2,000	1,250
1	vacuum tank	503	10	20,000	2,000	1,000
1	truck-tractor	514	10	59,000	6,000	4,000
	contingency (10%)	--	--	36,590	--	--

Life Cycle Cost = $1,060,847
Total Annual Cost = $ 26,200

*Appendix D.

†Unit costs.

Oils That Can and Cannot Be Handled--

All oils except the most viscous materials in Group III can be accommodated by System 4.

Approximate Volume of Spill Mass Which Can Be Handled--

System 4 includes the use of towable storage bags (Dracone). These collapsible vessels are air-deployable, capable of being brought to the recovery site quickly, and the largest can hold nearly 1,000 m^3 (260,000 gal). Ideally, they are used for the transport of concentrated recovered spill mass (subsequent to oil/water separation) from the workboat to a shore depot, at which point the recovered oil is pumped to a tank or vacuum truck. (The latter is only practical if short vertical distances, preferably 4.5 m or less, are involved.) The "donut" is a floating combination oil/water separator and fluids container. The towable craft floats partially submerged during loading of the oil/water mixture. The donut reduces total spill mass volume by functioning as a separator. When the oil and water separate, water is continually forced out of the bottom. The capacity of each donut is about 80 m^3 (21,200 gal).

Feasibility of Development Including Critical Elements--

All equipment components included in System 4 are available on the commercial market. Development of the equipment into a mobile Coast Guard response system would require little engineering expense other than proper sizing and acquisition of the components.

Environmental Impacts of System Operation and Mitigation Measures--

See System 2.

Approximate Size and Weight of the Equipment--

Table 12 shows the approximate dimensions and weights of each equipment element for System 4. Plans for each element are shown in the indicated figures.

TABLE 12. SYSTEM 4: DIMENSIONS AND WEIGHTS OF CRITICAL EQUIPMENT ELEMENTS

Equipment Element	Item No.	L(m)	W(m)	H(m)	D(m)	Weight(kg)	Fig*
Workboat	606	11.73	5.03	1.60	-	31,750	E-15
Pillow tank (towable) (in envelope)	203	3.0	2.0	2.0	-	743	E-1
Donut	303	7.60	4.60	6.70	-	20,000	E-3
Centrifugal pump†	1,016	1.50	0.45	0.60	-	184	E-21
Small workboat	605	9.14	3.66	1.40	-	14,500	E-14
Vacuum tank	503	9.80	-	3.35	1.68	7,484	E-8
Truck tractor	514	5.98	2.44	2.98	-	19,800	E-10

*For conceptual drawing, see figure number indicated, Appendix E.
†Worthington - 2-in CNGK-84, or equal.

Transportability by Existing Coast Guard Vessels and Aircraft Capability--

Appendix F describes the dimensions of various cargo holds for Coast Guard aircraft and vessels and the transportability of equipment included in System 4.

Transportability by Means Other than Coast Guard Vessel and Aircraft--

See Appendix F.

Special Requirements--

Specially trained Coast Guard personnel are required for installation and operation of all equipment included in System 4. During simultaneous operation of all equipment elements, it is estimated that a maximum of five persons is required as crew (includes workboats - 2, pillow tank(s) - 1, donut - 1, and pump - 1). Additional support may be required for transporting the crew to the field of operation.

Diesel fuel must also be provided for operation of the pumps and workboats. All units are provided with limited fuel storage. For prolonged operations, a small truck may be required for bringing additional fuel to the site.

SCENARIO B - OIL ONLY, NO DEBRIS, STORMY WEATHER, COLD AIR TEMPERATURE

Scenario B is defined as follows:

Oil dispersed in water, no solid debris, stormy weather, cold air temperature.

This scenario differs from scenario A in that the ambient air temperature is at or below $0^{o}C$.

Recovery Systems

Systems 1, 2, 3, and 4 may essentially be structured identically to those of Scenario A and applied to Scenario B. However, for No. 6 oil (Bunker C) there may be no capability for incineration at sea (System 1). Because of its relatively high density (s.g. $\approx$1.1), oil/water separation is not possible. Therefore, ten open-top roll-off containers (Galbreath R2290 - 45 yd^3) will be needed to contain the entire 304,000 ℓ (80,000 gal) of recovered oil and water. Each of these weighs 3,764 kg (8,300 lb).

Additional Fixed Equipment Required Under Scenario B

2 Pumps, motors	870 kg	(1,910 lb)
10 O.T. roll-offs	37,640 kg	(83,000 lb)
Misc. sump, piping	1,000 kg	2,200 lb)
Subtotal	39,510 kg	(87,110 lb)

Average density of spill mass:	Seawater	64 pcf
	Oil	68.6 pcf
Average		66.3 pcf

Therefore, the additional live load (spilled oil + water) is about 321,600 kg (709,210 lb), and the total additional weight is 361,110 kg (796,300 lb). The resultant reduction in freeboard would be about 0.6 m. This is also less than half the barge afterdeck freeboard (about 1.3 m). Thus, no overloading problems are anticipated.

The only significant difference between Scenario A and Scenario B is ambient air temperature. The colder temperatures of Scenario B dictate the use of a positive displacement pump rather than a centrifugal pump.

Substitution of a positive displacement pump in Systems 1 through 4, as described under Scenario A, will result in an increased capital cost of about $7,600 for Systems 1 through 3 (2 pumps), and $11,400 for System 4 (3 pumps). The total annual costs are also increased by about $2,500.

The dimensions of the alternative cold-weather pumps (Item No. 1015) are 1.50 m long, 0.46 m wide, and 0.60 m high. Each pump weighs 435 kg. These dimensions and weights do not significantly alter the system transportability, crew size, fuel requirements, or other factors determined for Scenario A.

SCENARIO G - OIL ONLY (SLUDGE OR SEDIMENT, INORGANIC SORBENTS MIX), CALM WEATHER, WARM AIR TEMPERATURE

Scenario G is defined as follows:

> Oil mainly consisting of heavy sludge, or mixed with soil, sand, sediments, organic sorbents. Environmental conditions include calm weather and warm air temperatures.

Oils considered under Scenario G include the five groups as defined in Appendix A. Environmental conditions include a moderate air temperature of from 15 to 25°C. Typical solid/oil mixture ratios up to 5 to 1 by volume are anticipated. Solids mixed with spill masses collected from off-shore operations will

probably consist of dredged sediment or sand slurries, or oil-sorbent mixtures. Debris recovered at onshore sites will not exhibit fluid characteristics and will probably consist of oil-contaminated sand or soils. It is anticipated that the sludges and slurry materials will be pumpable by centrifugal pumps or by progressive cavity systems.

General Systems for Oil Spill Mass Disposal: Fine Debris Materials

Figure 12 shows the general system options for receiving the oil/debris mixture from offshore or onshore recovery. Options are indicated for transporting dredge spoils or other materials to shore via a barge, a direct pipeline, or portable tanks on a workboat. Workboat tanks may be lifted to shore by crane or off loaded into a vacuum or tank truck. Interim processing of the spill-mass mixture to separate the oil and solids may also be conducted on site. Concentrated solids from the separator are pumped or conveyed to a tank for transfer to a contracted disposal off-site facility. The liquid fractions are conveyed to on-site treatment or disposal sites.

System 5

System 5 is defined as follows (Figure 13):

An offshore dredge or other primary recovery vessel (PRV), equipped with a centrifugal pump discharging dredge spoils into:

- Portable tanks on the deck of a barge or additional work-boat
- A pipeline leading to shore
- A barge with gunwales which is moored to the dredge, another workboat, or nearby pier structure.

The portable tanks may be off loaded from the workboat by a crane and placed on a flatbed truck for transport to an off-site facility. Alternatively, the contents of the portable tanks, barge, or pipeline may be discharged or pumped into a temporary storage tank, or transferred directly to a vacuum or tank truck for transport to an off-site facility. An additional pump must be provided where the contents of a portable tank or barge are to be placed in temporary on-shore storage or a tank truck.

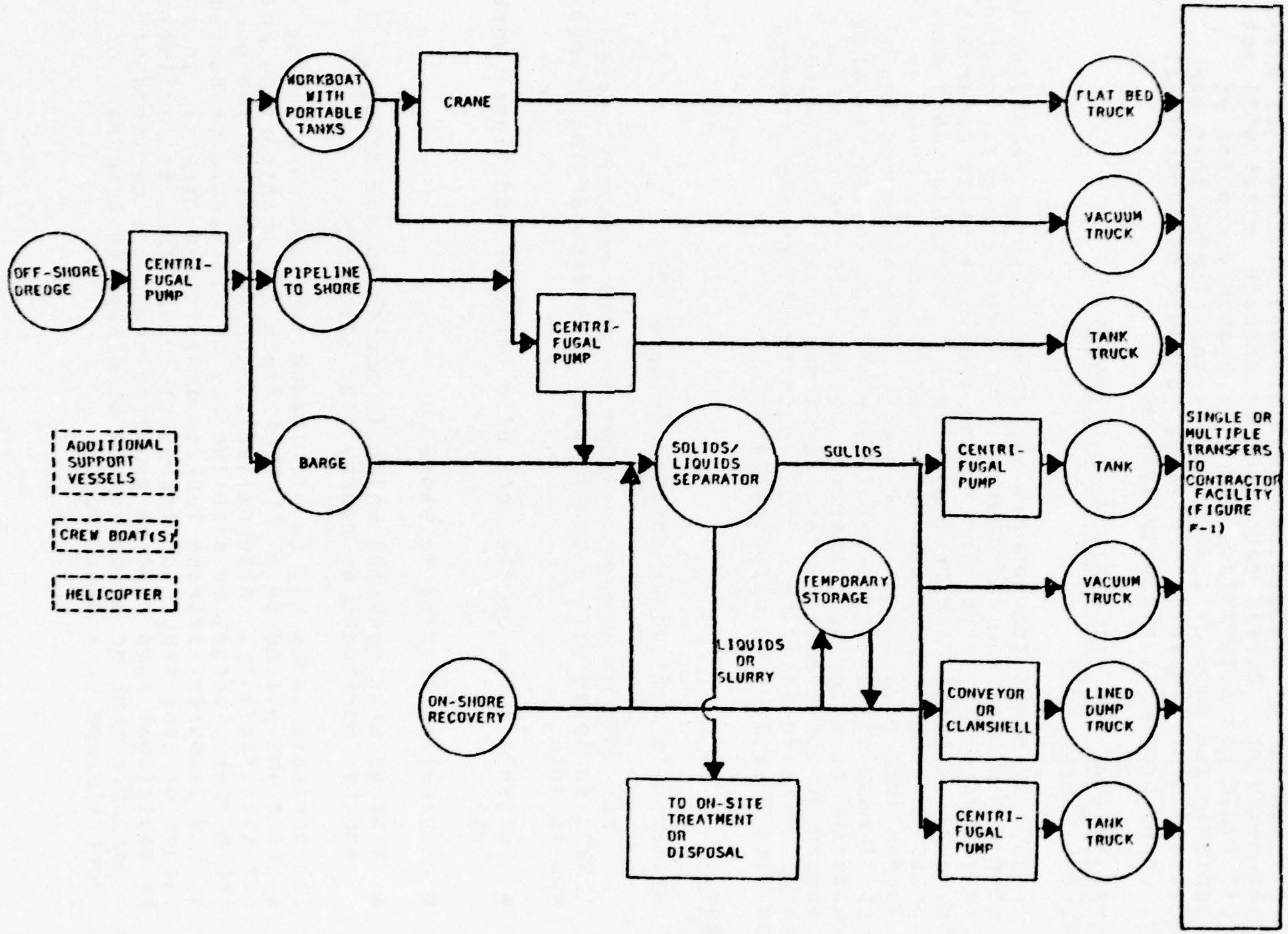

FIGURE 12. SCENARIOS G THROUGH L: GENERAL EXISTING SYSTEMS FOR STORAGE, TRANSFER, AND TRANSPORT OF RECOVERED SPILL MASSES.

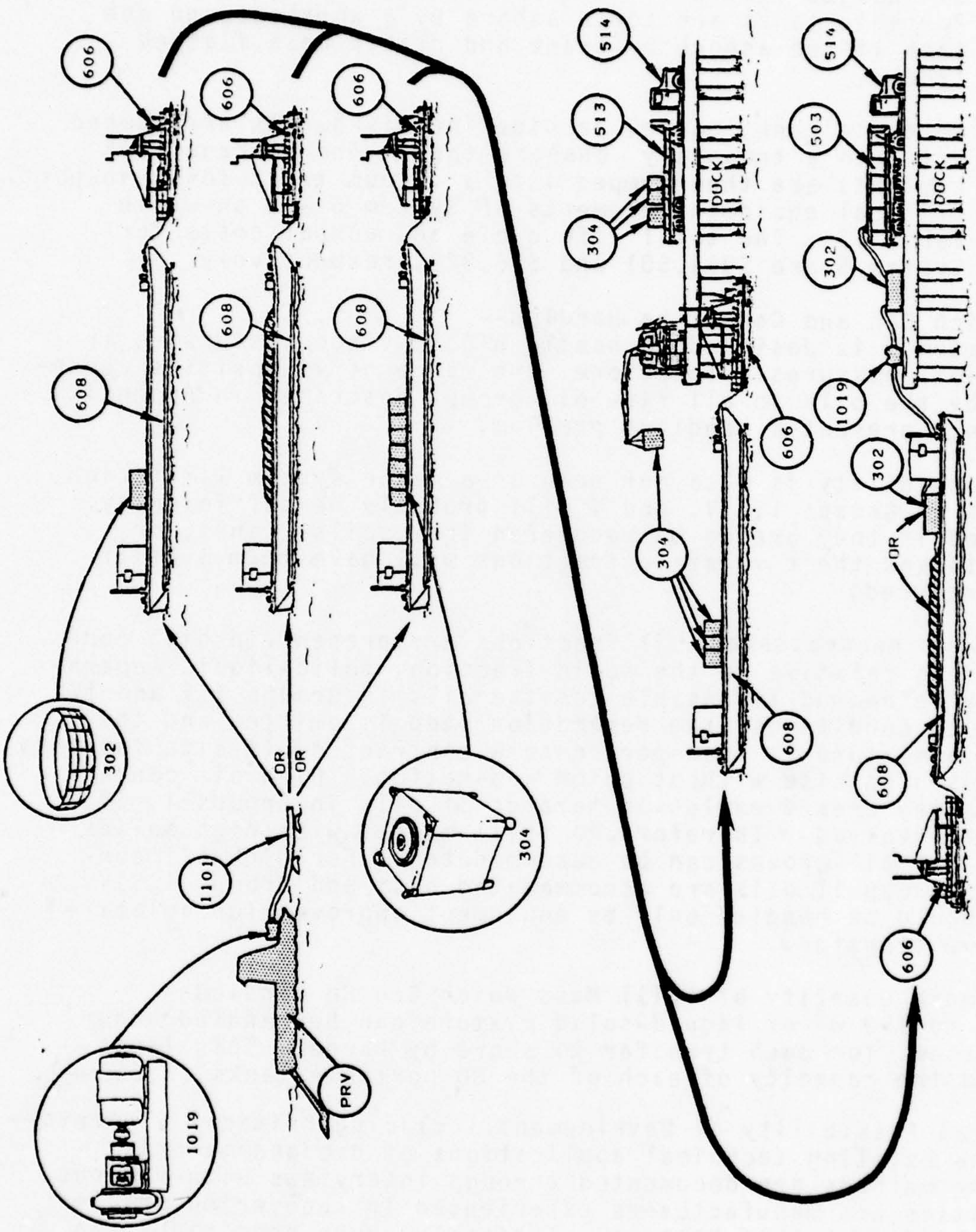

FIGURE 13. SYSTEM 5, SCENARIO G.

Two options are therefore included in System 5:

- Discharges stored in portable tanks on-barge (Figure 8). Portable tanks are towed ashore by a workboat, and are then lifted ashore by crane and placed on a flatbed truck.

- Portable tank, barge, or pipeline discharges are pumped out into a temporary onshore tank. The storage tank contents are then pumped into a vacuum truck for transport. Critical equipment elements of System 5 are shown in Table 13. The total life cycle and annual costs for System 5 are $944,501 and $35,820, respectively.

Oils Which Can and Cannot be Handled--

System 5 is designed to handle highly viscous slurries or sorbent-oil mixtures. Therefore, the range of viscosities represented by the oils in all five oil groups described in Appendix A does not present a handling problem.

Flammability is also not seen as a major system limitation. The oils in Groups I, IV, and V will probably be sufficiently weathered if they are to be recovered from soils, sands, or sediments, and their volatile fractions will have been substantially reduced.

Where nonweathered oil fractions are present in high concentrations relative to the solid fraction, solid-liquid separation may be deemed impossible for the oils in Groups III and IV. Under such conditions, the separation step is omitted and the oil/solid mixture is transported to a contracted off-site facility or disposed on site without prior separation. High oil concentrations may create explosion hazards if oils in Groups I, IV, or V are involved. Therefore, in spill masses with high solids content, all oil groups can be accommodated. For high oil contrations, Group II oils are accommodated best, and Groups I, IV, and V should be handled only by equipment approved for volatile petroleum transfer.

Approximate Quantity of Spill Mass Which Can Be Handled--

Up to 180 m^3 of liquid-solid mixture can be handled under this system for each transfer to shore by barge. This limit reflects the capacity of each of the 80 portable tanks (2.25 m^3).

Technical Feasibility of Development Including Critical Elements--

The existing technical applications of dredged material handling methods are documented through interviews with various authorities and manufacturers experienced in recovering spilled materials from harbor bottoms. Typically, such operations can only be conducted under mild sea conditions, and where the contaminated bottom is shallow and accessible. Primary recovery vessels are available which can conduct small dredging operations with limited resuspension of sediments (see Equipment Item No. 610

TABLE 13. SYSTEM 5: CRITICAL EQUIPMENT ELEMENTS

Qty	Equipment Element	Item* No.	Estimated Life (Yr)	Capital Cost (1978 $)	Approximate Annual O&M Costs ($)	Estimated Salvage Value ($)
1	workboat	606	20	80,000	5,600	4,000
1	barge	608	20	150,000	5,000	8,000
2	centrifugal solids pump (4MF-11)	1019	10	8,600 (4,300)†	600	430
1	centrifugal solids pump (5MF-15)	1019	10	13,800	1,000	700
80	portable tanks	304	10	72,000 (900)†	13,000	3,000
200 ft	8-in pipeline and floats	1101	5	9,800 (49)†	- 0 -	- 0 -
1	large shore tank (open top, portable) (30 ft dia x 12 ft high)	302	20	9,500	1,000	500
1	crane	810	10	12,500	750	600
1	flatbed trailer	513	10	8,700	870	400
1	truck-tractor	514	10	59,000	6,000	4,000
1	vacuum tank	503	10	20,000	2,000	1,000
	contingency (10%)	--	--	44,390	--	--

Life Cycle Cost = $944,501
Total Annual Cost = $ 35,820

*Appendix D.
†Unit costs.

and 611, Appendix D). However, careful analysis and control measures must be undertaken to avoid recontamination of the water column.

Since much of the pumping and spill mass-transfer capabilities are associated with the primary recovery vessel, it is included as an integral part of this particular disposal system. The vessel is readily trailerable to the site of operations.

Environmental Impacts of System Operation and Mitigation Measures--
Environmental impacts may occur with System 5 at any of several points along the flow of debris handling:

- Water-to-shore transfer of the oil-soaked solids
- Accidental overfilling of temporary storage tanks
- Accidental spills during vacuum truck pumpout of the temporary storage tanks.

The transport and use of the heavy portable equipment at sensitive shoreline areas may also result in damage to terrestrial or aquatic plant life and fauna.

The potential for further water contamination by drippings or spillage during debris transfers may be minimized according to techniques described for System 4.

Approximate Size and Weight of the Equipment--
Table 14 shows the approximate dimensions and weights of each equipment element of System 5. Plans for each element are shown in the indicated figures.

TABLE 14. SYSTEM 5: DIMENSIONS AND WEIGHTS OF CRITICAL EQUIPMENT ELEMENTS

Equipment element	Item no.	L (m)	W (m)	H (m)	D (m)	Weight	Fig.*
Workboat	606	11.73	5.03	1.60	-	31,750	E-15
Barge	608	32.31	7.92	2.59	-	90,710	E-16
Pump + motor (8MF-15) solids	1019	1.97	0.82	0.64	-	180	
Pump + motor (4MF-11)	1019	1.34	0.82	0.64	-	180	
Portable tanks	304	1.07	1.20	1.80		165	E-4
Tanks, storage	302	1.2	3.0	1.2	-	2,700	E-2
Crane (envelope)	810	8.70†	-	10.00†	-	2,110	E-17
Pipeline	1101	61.00	-	-	0.20	799	
Flatbed trailer	513	13.0	2.64	1.20	-	4,590	E-9
Truck-tractor	514	5.98	2.44	2.98	-	19,800	E-10
Vacuum tank	503	9.80	-	3.35	1.68	7,484	E-8

*For conceptual drawing, see figure indicated, Appendix E.

†Key dimensions: L = lateral reach, H = lift distance.

Transportability by Existing Coast Guard Vessel and Aircraft Capability--

Appendix F describes the dimensions of various cargo holds for Coast Guard aircraft and vessels, and the transportability of equipment included in System 5.

Transportability by Means Other Than Coast Guard Vessel and Aircraft--

See Appendix F.

Special Requirements--

Specially trained Coast Guard personnel are required for installation and operation of all equipment included in System 5. During simultaneous operation of all equipment elements, it is estimated that a maximum of eight persons are required as crew, including: workboat - 1, barge - 1, crane - 2, pump - 1, tank - 1, trucks - 2. Additional support transport may be required for transporting the crew to the field of operation.

Diesel fuel must also be provided for operation of the pumps, crane, and workboat.

System 6

System 6 is described as follows (Figure 14):

> Oil/solid mixtures are collected from off-shore operations (PRV) in an identical manner to that described in System 5. However, instead of moving the debris to an off-site facility by truck, the materials are passed either directly or via temporary on-shore storage to a solids/liquid separator. Effluent solids which are still in a slurry form are transferred from the separation unit to temporary storage. The solids are then removed by vacuum truck and transported to an off-site facility. Nonpumpable solids may be removed from the separation process by a conveyor or by clamshell, and placed in a lined dump truck for removal. Sludges from the process may also be disposed on-site by proper land disposal techniques. Natural solids such as sands may be returned to the environment. The liquid effluents from the separation process are transferred to additional on-site treatment.

Two solid waste handling options exist under System 6, as described below:

- Separator effluent solids that are pumpable may be removed via temporary storage by a vacuum truck.
- Solids that are not pumpable must be removed from the processing site by a conveyor or clamshell, and placed in a lined dump truck for removal.

Critical equipment elements for System6 are shown in Table 15.

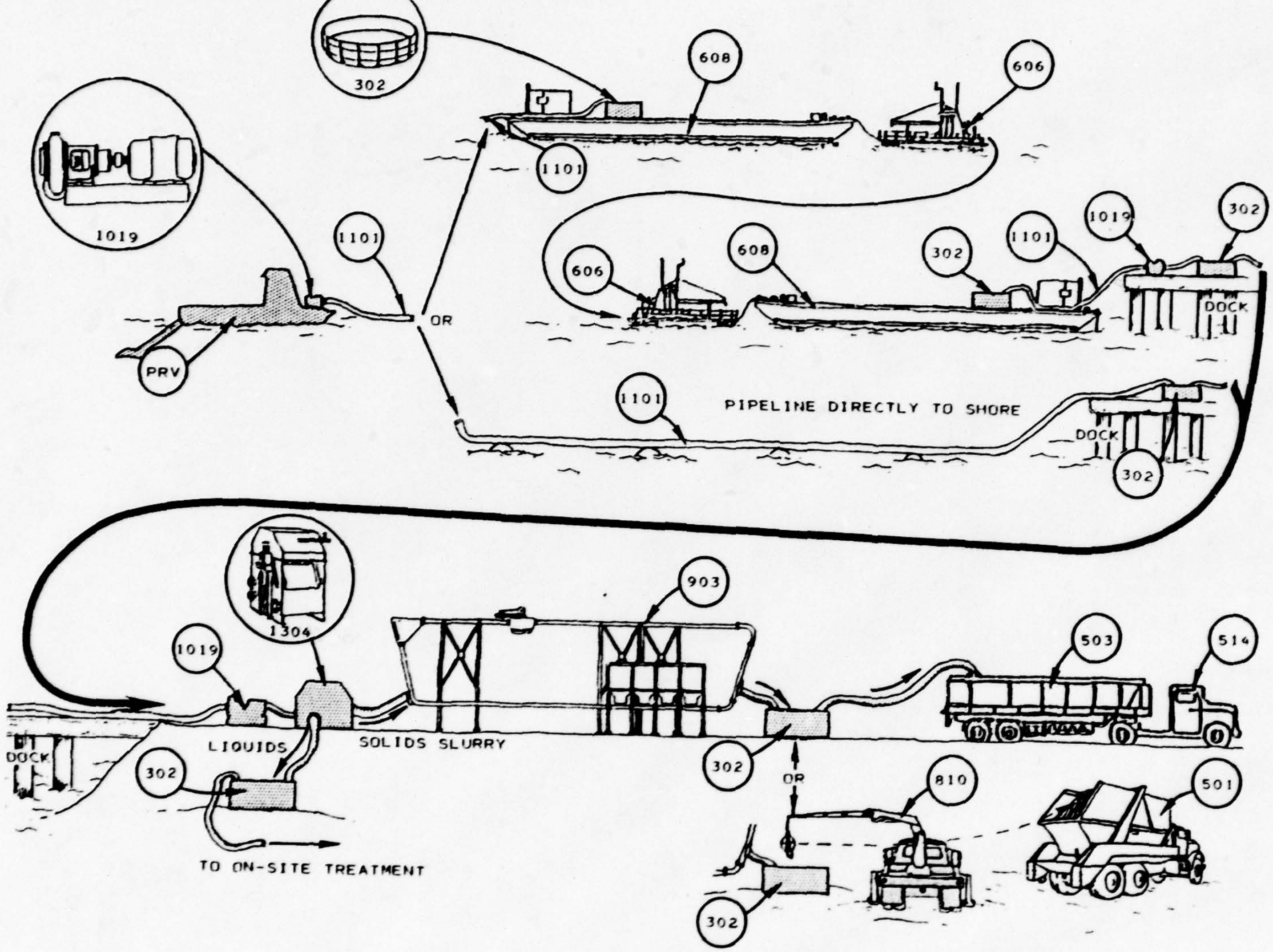

FIGURE 14. SYSTEM 6, SCENARIO G.

TABLE 15. SYSTEM 6 : CRITICAL EQUIPMENT ELEMENTS

Qty	Equipment Element	Item No.*	Estimated Life (Yr)	Capital Cost (1978 $)	Approximate Annual O&M Costs ($)	Estimated Salvage Value ($)
1	workboat	606	20	80,000	5,600	4,000
1	barge	608	20	150,000	5,000	8,000
2	centrifugal solids pump (4MF-11)	1019	10	8,600 (4,300)*	600	430
1	centrifugal solids pump (8MF-15)	1019	10	13,800	1,000	700
16	temp. storage tank (9 ft dia x 8 ft high)	302	20	32,000 (2,000)†	3,000	1,600
1	large shore tank (30 ft dia x 12 ft high)	302	20	9,500	1,000	500
200 ft	8-in pipeline and floats	1101	5	9,800 (49)†	- 0 -	- 0 -
1	liquids/solids separator	1304	10	30,000	1,500	1,500
1	crane	810	10	12,500	750	600
1	conveyor	903	5	7,710	500	400
1	vacuum tank	503	10	20,000	2,000	1,000
1	truck-tractor	514	10	59,000	6,000	4,000
1	dump truck	501	10	50,000	3,700	2,500
	contingency (10%)	--	--	48,291	--	--

Life Cycle Cost = $1,001,425
Total Annual Cost = $ 30,650

*Appendix D.
†Unit costs.

Oils Which Can and Cannot Be Handled--

For Groups III and V, see System 5. Spill mass characterized by oil fractions present in high concentrations relative to the debris fraction may not be processed by liquid/solid separation. Under such conditions, the separation step is omitted, and the oil/solid mixture is transported to an off-site facility or disposed on-site as described in System 5.

Approximate Quantity of Spill Mass Which Can Be Handled--

See System 5.

Technical Feasibility of Development Including Critical Elements--

The existing technical applications of on-site liquids/solids separation are documented through interviews with equipment manufacturers. All critical elements for the various system options in System 6 are available on the commercial market, and may be readily assembled into a well-defined portable system for transport to the recovery site.

Environmental Impacts of System Operation and Mitigation Measures--

See System 5.

Approximate Size and Weight of the Equipment--

Table 16 shows the approximate dimensions and weights of each equipment element included in System 6.

TABLE 16. SYSTEM 6: DIMENSIONS AND WEIGHTS OF CRITICAL EQUIPMENT ELEMENTS

Equipment element	Item no.	L (m)	W (m)	H (m)	D (m)	Weight(kg)	Fig.*
Workboat (1)	606	11.73	5.03	1.60	-	31,750	E-15
Barge (1)	608	32.31	7.92	2.59	-	90,710	E-16
Centrifugal solids pump (4MF-11) (2)	1019	1.34	0.82	0.64	-	180	
Centrifugal solids pump (8MF-15) (1)	1019	1.97	0.95	1.00	-	480	
Open-top tank (in envelopes) (16)	302	1.2	3.0	0.3	-	885	E-2
Large shore tank (in envelopes) (1)	302	1.2	3.0	1.2	-	2,700	E-2
8-ft pipeline	1101	61.00	-	-	0.203	799	
Liquid/solids separator (1)	1304	3.90	1.70	1.10	-	1,200	E-23
Crane (1)	810	8.70†	-	10.00†	-	2,110	E-17
Conveyor (1)	903	Var	-	-	0.25	Var	E-19
Vacuum tank (1)	503	9.80	2.43	3.35	-	7,484	E-8
Truck-tractor (1)	514	5.98	2.44	2.98	-	19,800	E-10
Dump truck (1)	501	5.10	2.43	1.80	-	2,358	E-7

*For conceptual drawing, see figure number indicated, Appendix E.
†Key dimensions: L = lateral reach; H = lift distance.

Transportability by Existing Coast Guard Vessel and Aircraft Capability--
Appendix F describes the dimensions of various cargo holds for Coast Guard aircraft and vessels, and the transportability of equipment included in System 6.

Transportability by Means Other Than Coast Guard Vessel and Aircraft--
See Appendix F.

Special Requirements--
The limiting elements in System 6 are trucks (Item Nos. 503 and 506), which cannot be transported to field sites by sea or air. Where roads are not established, debris transfer may be conducted at alternate sites by ship or lifting aircraft such as skycranes.

Specially trained Coast Guard personnel are required for installation and operation of all equipment included in System 6. During simultaneous operation of all equipment elements, it is estimated that a maximum of 10 persons is required as crew, including: workboat - 1, barge - 1, crane - 2, pump - 1, conveyor - 1, tank - 1, liquid/solids separator - 1, trucks - 2. Additional support transport may be required for transporting the crew to the field of operation.

Diesel fuel must also be provided for operation of the pump, crane, and workboat. These units are provided with limited fuel storage for prolonged operations; a small tank truck may be required for bringing additional fuel to the site.

System 7

System 7 is defined as follows (Figure 15):

> An on-shore recovery device (such as a bucket loader or crane with clamshell) deposits contaminated soils or sands into lined dump trucks. If the recovered material is a slurry, it is pumped into temporary storage by 1019 pumps and then loaded into a vacuum track for transport to off-site processing. Otherwise, material is passed through a solid/liquid separator as described in System 6.

All spill mass handling, treatment, and disposal options included in Systems 5 and 6 are also included in System 7. Costs of critical equipment elements are shown in Table 17.

Oils Which Can and Cannot Be Handled--
See System 6.

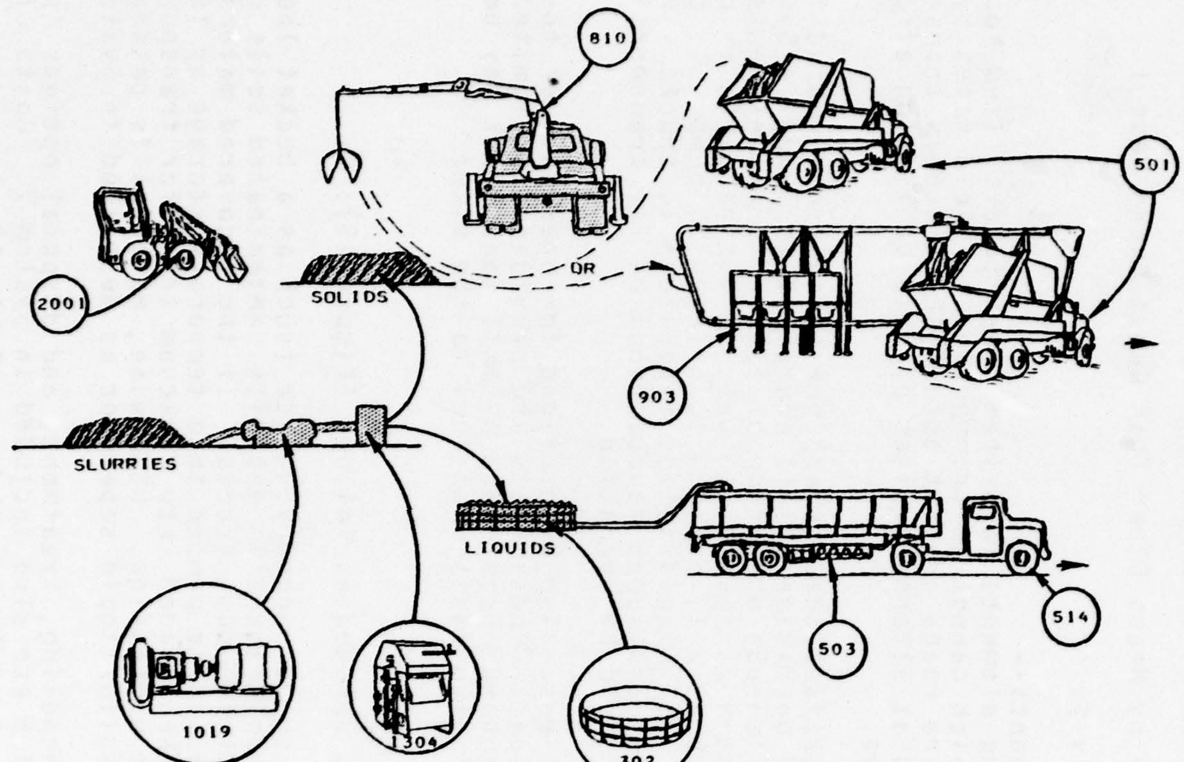

FIGURE 15. SYSTEM 7, SCENARIO G.

TABLE 17. SYSTEM 7 : CRITICAL EQUIPMENT ELEMENTS

Qty	Equipment Element	Item No.*	Estimated Life (Yr)	Capital Cost (1978 $)	Approximate Annual O&M Costs ($)	Estimated Salvage Value ($)
1	tractor with backhoe	1001	10	24,000	2,400	1,200
1	crane with clamshell	810	10	12,500	750	600
1	centrifugal solids pump (8MF-15)	1019	10	13,800	1,000	700
1	open-top tank (30 ft dia x 12 ft high)	302	20	9,500	1,000	500
1	liquids/solids separator	1304	10	30,000	1,500	1,500
1	conveyor	903	5	7,710	500	400
1	dump truck	501	10	50,000	3,700	2,500
1	vacuum tank	503	10	20,000	2,200	1,000
1	truck-tractor	514	10	59,000	6,000	4,000
	contingency (10%)	--	--	22,651	--	--

Life Cycle Cost = $618,683
Total Annual Cost = $ 19,050

*Appendix D.

Approximate Quantity of Spill Mass Which Can Be Handled--
See System 6.

Technical Feasibility of Development Including Criteria Elements--
See System 6.

Environmental Impacts of System Operations and Mitigation Measures--
See System 5. Potential impacts associated with water-to-shore transfer of oil-soaked solids are not a problem, however.

Approximate Size and Weight of the Equipment--
Table 18 shows the dimensions and weights of each equipment element included in System 7.

TABLE 18. SYSTEM 7: DIMENSIONS AND WEIGHTS OF CRITICAL EQUIPMENT ELEMENTS

Equipment element	Item no.	L (m)	W (m)	H (m)	D (m)	Weight(kg)	Fig.*
Tractor with backhoe	1001	4.57	2.26	3.76	-	4,540	E-32
Crane with clamshell	810	8.70†	-	10.00†	-	2,110	E-17
Solids pump + motor	1019	1.97	0.95	1.00	-	480	
Tank, storage (1)	302	1.2	3.0	0.3	-	2,700	E-2
Truck, dump	501	5.10	2.43	1.80	-	2,358	E-7
Liquids/solids separator	1304	3.90	1.70	1.10	-	1,200	E-23
Conveyor	903	Var.	-	-	0.25	Var.	E-19
Vacuum tank	503	9.80	2.43	3.35	-	7,484	E-8
Truck tractor	514	5.98	2.44	2.98	-	19,800	E-10

*For conceptual drawing, see figure number indicated, Appendix E.
†Key dimensions: L = lateral reach, H = lift distance.

Transportability by Existing Coast Guard Vessel and Aircraft Capability--
See Appendix F.

Transportability by Means Other Than Coast Guard Vessel and Aircraft--
See Appendix F.

Special Requirements--
See Systems 5 and 6.

SCENARIO H - OIL ONLY (SLUDGE OR SEDIMENT, INORGANIC SORBENTS MIX), STORMY WEATHER, AIR TEMPERATURE COLD

This scenario differs from Scenario G in that the ambient air temperature is at or below 0°C. The high viscosity of 1,000 m^3 of petroleum products at 0°C (about 100,000 centistokes) is such that conventional pumping techniques using positive displacement pumps are not applicable. The use of a pipeline to shore, discussed in Scenario G, System 5, is therefore not possible.

The most practical means of transfer, either into portable tanks or onto the deck of a barge or workboat, is with a conveyor. Accordingly, a tubular conveyor, similar to the one identified in Scenario G, System 6, is a practical solution. Since the objective of this recovery system is to transfer 1,000 m^3 in a reasonable time period, it is assumed that the tube contains chain-connected circular flights about 76.2 cm (30 in) on centers. For a chain speed of 1.25 ft/sec (75 ft/min), the volumetric delivery rate is 30 cfm. The time period for transfer of 1,000 m^3 is therefore:

$$t = \frac{Vol}{Q} = \frac{1{,}000\left(35.31\ ft^3/m^3\right)}{30} = 1{,}177\ \text{min}\ (\sim 20\ \text{hr})$$

This would not appear to be an unreasonably long time for recovery of over 35,000 ft^3 of fairly dense matter.

In estimating the power requirement, the following assumptions are made:

Density of spill mass, γ = 120 lb ft^3

Coefficient of friction on walls of duct, μ = 0.65

Total height solids must be transferred, h = 20 ft, (in a distance of 75 ft)

- Work done (per min) to overcome friction (velocity = 75 ft/min)

$$\dot{W}_1 = Q\ \gamma\mu V = \left(30\ \frac{ft^3}{min}\right)\left(120\ \frac{lb}{ft^3}\right)(0.65)\ (75)$$

$$\dot{W}_I = 175{,}500\ \text{ft-lb/min}$$

- Work done (per min) to raise solids 20 ft

$$\dot{W} = Q\gamma\ h = \left(30\ \frac{ft^3}{min}\right)\left(120\ \frac{lb}{ft^3}\right)(20)$$

$$\dot{W}_2 = 72{,}000\ \text{ft-lb/min}$$

$$\text{Total}\ \dot{W} = 247{,}500\ \text{ft lb/min}$$

Assuming the overall efficiency of the chain drive system is 50 percent, the power requirement is:

$$\text{Power} = \frac{\dot{W}}{33{,}000} = \frac{247{,}500}{33{,}000\ (0.5)} = 15\ \text{hp}$$

Use of a 20-25 hp drive motor appears to be sufficient.

System 6 is therefore recommended for handling oil/debris mixtures under conditions anticipated for Scenario H.

SCENARIO M - OIL/ORGANIC SOLIDS MIX, CALM WEATHER, WARM AIR TEMPERATURE

Scenario M is defined as follows:

> Oil mixed with large amounts of organic solids (seaweed, storm debris, organic sorbents). The environmental conditions include calm weather and warm air temperatures.

Oils considered under Scenario M include the five groups as defined in Appendix A. Environmental conditions include a moderate air temperature of from 15 to 25°C. Typically, the total spill mass volume can be as much as 100 times the volume of the original spilled component.

The debris materials described by Scenario M include sea grass, seaweed, driftwood, flotsam, organic sorbents, and miscellaneous floatable debris.

General Systems

Recovery operations by an off-shore vessel similar to the modified YSD Coyote or Raccoon (used by the Corps of Engineers, Sausalito, California) have occurred. A low-mounted chain-link debris net about 6 m (20 ft) wide and capable of lifting about 10,000 kg (10 tons) is used for picking up the spill mass. The volumetric ratio of solids to oil has been taken as 100:1 in hypothetical spill events (worst case).

If open-top roll-offs are employed for temporary storage, on-board washing, and separation (screening and draining), it is first essential to consider the possibility that more than one separation is involved. For instance, the afterdeck of a recovery vessel, such as the Coyote (YSD), is capable of holding six open-top roll-offs (total capacity, about 205m^3). No fewer than 18 boat-loads of spill mass are therefore required, in order that the initial oil/solids separation by washing, screening, and draining be accomplished.

Consideration has been given to inserting a plastic liner in the midship tanks of a barge (SWOB-1) and placing the spill mass there. Assuming that the entire volume (desk-to-gunwale height of 1.6 m and about 163 m^2 of deck area) is available, about 262 m^3, more than the combined volume of the above six roll-offs, is provided. Economics, in terms of lower capital outlay, may also make this alternative attractive, especially since 15, rather than 18, off-loading trips would be involved.

Roll-off bins are superior to open-top cylindrical tanks of the type recommended in Scenario A, because of the smaller deck space required. They can also be off loaded to dock-site by crane.

Assuming the average density of the recovered solids to be about 500 kg/m^3, each pick-up will yield a volume of about 20 m^3 (700 ft^3). Thus, about 190 separate pickups are entailed in recovery of the entire spill. Assuming that each pickup takes 1/2 hr, and that two are required in order to fill a single roll-off bin, then all eight roll-offs on board may be filled within a 12-hr period. Total recovery is therefore estimated to occupy about 1 wk, unless more than one recovery vessel and one auxiliary barge are involved.

Figure 16 shows how debris materials are then transferred to shore and stockpiled, or moved directly to trucks for transfer to off-site processing. Onshore treatment options include washing or screening of the debris to remove excess oil. For certain organic debris materials (such as driftwood), a shredder or chipper may be used to reduce the solid material size and increase transportation or disposal efficiency. Oil-soaked chips or other organic fines resemble spill masses discussed under Scenario G, and may be further processed by equipment described by Systems 5, 6, or 7, or immediately disposed of.

System 8

System 8 is defined as follows (Figure 17):

> Materials from the primary off-shore recovery vessel (PRV) are placed into portable bins with screened openings on the deck of a workboat, or into a barge or small crane-liftable scows towed by a workboat. Some oils may be removed from the solid/liquid mixture by on-board separation. Removed fluids are transferred to shore in a similar manner as described under Scenario A. The debris is then transferred to shore. A crane with a clamshell may be used to remove the solid debris from the bins, barge, or scows, or the bins or scows may be transferred by crane to shore. The materials may then be temporarily stockpiled on shore using liners, or placed into a lined dump truck for removal to an off-site facility. If the materials are in portable bins or small scows, these may be placed directly onto a flatbed truck or stake truck without need for direct debris rehandling.

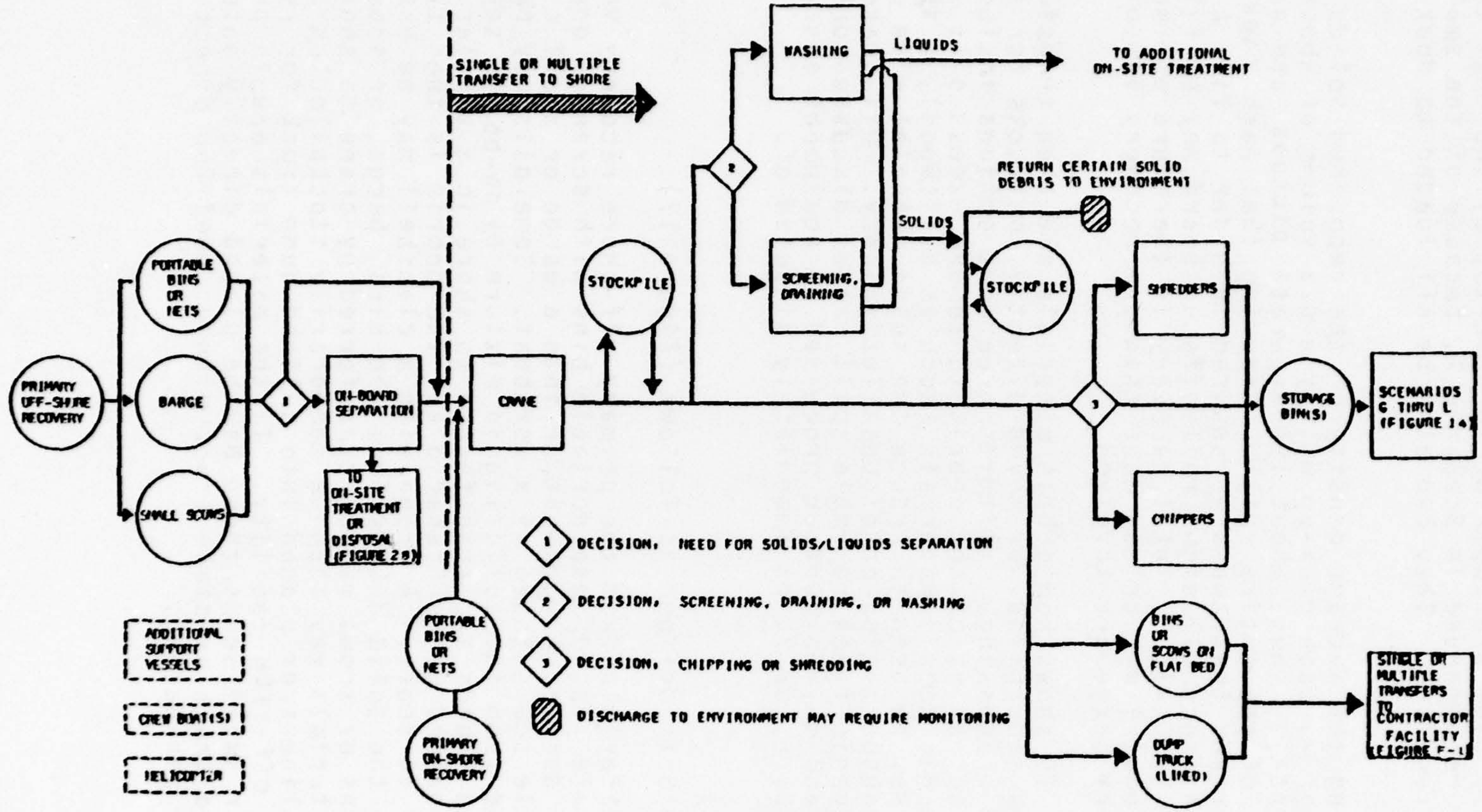

FIGURE 16. SCENARIOS M THROUGH R: GENERAL EXISTING SYSTEMS FOR STORAGE, TRANSFER, AND TRANSPORT OF RECOVERED SPILL MASSES.

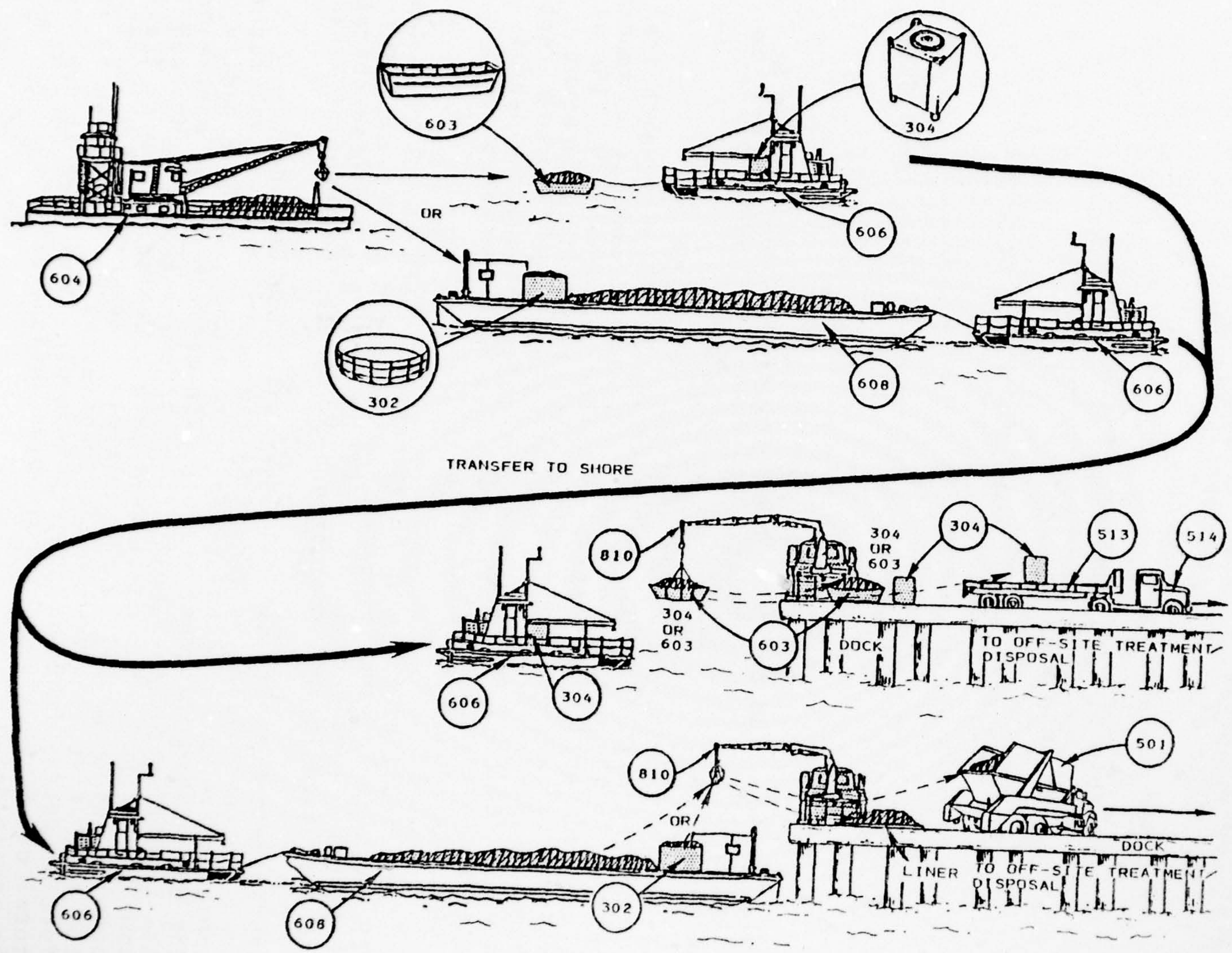

FIGURE 17. SYSTEM 8, SCENARIO M.

The alternatives included in System 8 actually describe several system options for the transfer of spill mass to shore and transport to off-site disposal facilities:

Transfer to shore

- Portable bins on the deck of a workboat
- Barge towed by a workboat
- Small crane-liftable scows towed by a workboat.

Transfer to off-site facility

- Crane with clamshell - temporary storage - lined dump truck
- Crane lift to flatbed truck.

Table 19 shows the critical equipment elements for System 8. System 8 total life cycle cost and annual cost are $1,533,569 and $48,520, respectively.

Oils Which Can and Cannot Be Handled--

System 8 is designed to handle any of the oils which are included in the groups defined in Appendix A, and may be adhering to the recovered solid debris described by Scenario M. The oils in Groups I, IV, and V are usually volatile and may present special handling problems. However, experience has shown that once the fuel has adhered to debris materials, and the debris materials are collected, the fuels may have weathered sufficiently to reduce the initial volatility.

Difficulties may also be encountered with the oils in Groups III and V during the on-board separation and subsequent onshore treatment of drained fluids. Factors controlling these operations are discussed in this section under On-Site Treatment of Fluids.

Approximate Quantity of Spill Mass Which Can Be Handled--

The controlling factor of System 8, in terms of volumetric capacity are the loading/unloading rate and storage capacity of the over-water transport vessels. In maximum volume operations, it is anticipated that most of the material may be contained in some manner for a period of days (e.g., behind a dike or floating boom). This would allow for multiple transfers of debris from the point of collection to the transfer point. Assuming 18 transfers of debris-laden transports in a period of several days, a total of up to 3,800 m^3 of oil plus solid debris could ideally be accommodated.

TABLE 19. SYSTEM 8: CRITICAL EQUIPMENT ELEMENTS

Qty	Equipment Element	Item No.*	Estimated Life (Yr)	Capital Cost (1978 $)	Approximate Annual O&M Costs ($)	Estimated Salvage Value ($)
1	collection vessel	604	20	390,000	15,000	19,500
1	workboat	606	20	80,000	5,600	4,000
1	barge	608	20	150,000	5,000	8,000
20	scows	603	10	20,000 (2,000)†	200	100
2	centrifugal pump and motor	016	10	12,600 (6,300)†	600	120
6	open-top roll-off bins	515	10	18,000 (3,000)†	300	3,000
2	oil/water separator	213	20	27,800 (13,900)†	3,000	1,400
40	portable tanks	304	10	36,000 (900)†	6,500	1,500
1	temp. storage tank (30 ft dia x 12 ft high)	302	20	9,500	1,000	500
1	crane	810	10	12,500	750	600
1	flatbed trailer	513	10	8,700	870	400
1	truck-tractor	514	10	59,000	6,000	4,000
1	dump truck	501	10	50,000	3,700	2,500
	contingency (10%)	--	--	87,410	--	--

Life Cycle Cost = $1,533,569
Total Annual Cost = $ 48,520

*Appendix D.
†Unit costs.

Technical Feasibility of Development Including Critical Elements--

The method of debris management described by System 8 is presently in practice in major harbors throughout the world to maintain navigable waterways and moorages. All critical elements for this system are available on the market, and may be readily assembled into a well-defined system for operation at ocean or lake recovery sites.

Portability of some of the equipment included in options under System 9 is questionable. The barge and large workboat must be brought from their present moorings to the site of operation via navigable waterways, yet other portable vessels can be substituted. The small crane-liftable scows and the workboat may be trailered or air-lifted into the site of operation.

Environmental Impacts of System Operation and Mitigation Measures--

Environmental impacts may occur at any of several points along the flow of debris handling:

- During shipboard handling-processing of the collected debris
- At water-to-shore transfer of the oil-soaked solids
- From stockpiling of debris on shore, which creates a potential for leaching of oils into surrounding soils or run-off of fluids into adjacent watercourses.

The potential for accidental redischarge of spill mass materials back into the water or soils is always a problem during spill cleanup operations. However, the benefits realized from accepting this risk far outweigh the probable environmental contamination which would result if nothing were done at all.

To minimize the potential for re-contamination through shipboard processing, the ship should be present in the immediate area of containment. This will enable booms, skimmer devices, and debris recovery craft to respond and easily contain any secondary discharges.

The potential for further water contamination from drippings or spillage during water-to-shore transfers of debris cargos may be minimized by placing an oil containment boom in the water around the off-loaded vessel and the swing radii of the off-loading cranes.

Sunlight-resistant membrane liners should be placed under any debris to be stockpiled prior to delivery to an off-site facility. To ensure that no leaching of oil to the underlying soils occurs, the ground surface should be smoothed off and cleared of any rocks or branches which might penetrate the membrane. If the debris to be stockpiled is jagged and irregular,

it may be best to apply a bed of straw, sand, or some other cushioning agent over the liner to prevent puncture.

When oily debris is stockpiled in the open, rainwater could tend to leach oils into nearby soils, streams or waterways. This can be prevented by covering the debris with plastic or water-proof tarps and erecting a small berm around the pile. Ditches or berms provide drainage control and collect runoff which can be impounded or pumped into storage tanks for later treatment.

Approximate Size and Weight of the Equipment--

Table 20 shows the approximate dimensions and weights of each equipment element included in System 8.

TABLE 20. SYSTEM 8: DIMENSIONS AND WEIGHTS OF CRITICAL EQUIPMENT ELEMENTS

Equipment element	Item no.	L (m)	W (m)	H (m)	Weight (kg)	Fig.*
Recovery vessel	604	29.59	10.85	2.13	218,450	E-13
Workboat	606	11.73	5.03	1.60	31.750	E-15
Barge	608	32.31	7.92	2.59	90,710	E-16
Oil/water separator	1213	3.86	2.08	1.50	1,910	E-22
Centrifugal pump + motor	1016	1.50	0.45	0.60	184	E-21
Portable tanks	304	1.07	1.20	1.80	165	E-4
Crane	810	8.70†	-	10.00†	2,110	E-17
Open-top roll-offs	515	6.78	2.24	2.29	3,764	E-11
Open-top storage tanks (in envelope)	302	1.2	3.0	1.2	2,700	E-2
Dump truck	501	5.1	2.43	1.80	2,358	E-7
Flat bed trailer	513	13.0	2.64	1.20	4,590	E-9
Scow	603	4.27	2.44	0.54	272	E-12
Truck-tractor	514	5.98	2.44	2.98	19,800	E-10

*For conceptual drawing, see figure indicated, Appendix E.
†Key dimensions: L = lateral reach, H = lift distance.

Transportability by Existing Coast Guard Vessels and Aircraft Capability--

Appendix F describes the dimensions of various cargo holds for Coast Guard aircraft and vessels and transportability of equipment included in System 8.

Transportability by Means Other Than Coast Guard Vessel and Aircraft--

See Appendix F.

Special Requirements--

The limiting element in System 8 is the barge (Item No. 608) which requires towing to the site by either the recovery

vessel or a workboat. The crane may be mounted on the flatbed truck, provided that the legal height limits are not exceeded.

Specially trained Coast Guard personnel are required for installation and operation of all equipment included in System 8. During simultaneous operation of all equipment elements, it is estimated that a maximum of seven persons are required as crew, including: barges - 2, crane - 1, pump - 1, storage tank - 1, trucks - 2. Additional support may be required for transporting the crew to the field of operation.

Diesel fuel must also be provided for operation of the workboat and crane. Pumps 1015 and 1016 may also be diesel-powered. These units are provided with limited on-board fuel storage. For prolonged operations, a small tank truck may be required for bringing additional fuel to the site.

System 9

System 9 is defined as follows (Figure 18):

> The recovered spill mass from the primary recovery vessel (PRV) is placed in a barge equipped with a membrane liner, similar to System 8. Washing, screening, and draining take place onshore and liquid effluent is submitted to additional on-site treatment. Solids from the washing and draining operation are either temporarily stockpiled or loaded directly into a lined dump truck by a crane equipped with clamshell, and are transported to an off-site facility. Alternatively, the debris is lifted into smaller portable containers, which are then loaded onto flatbed truck(s) and transported off site.

Table 21 shows the critical equipment elements for System 9. The system life cycle and annual costs are $1,370,810 and $41,320, respectively.

Oils Which Can and Cannot Be Handled--
See System 8.

Approximate Quantity of Spill Mass Which Can Be Handled--
See System 8.

Technical Feasibility of Development Including Critical Elements--
See System 8.

Environmental Impacts of System Operations and Mitigation Measures--
See System 8.

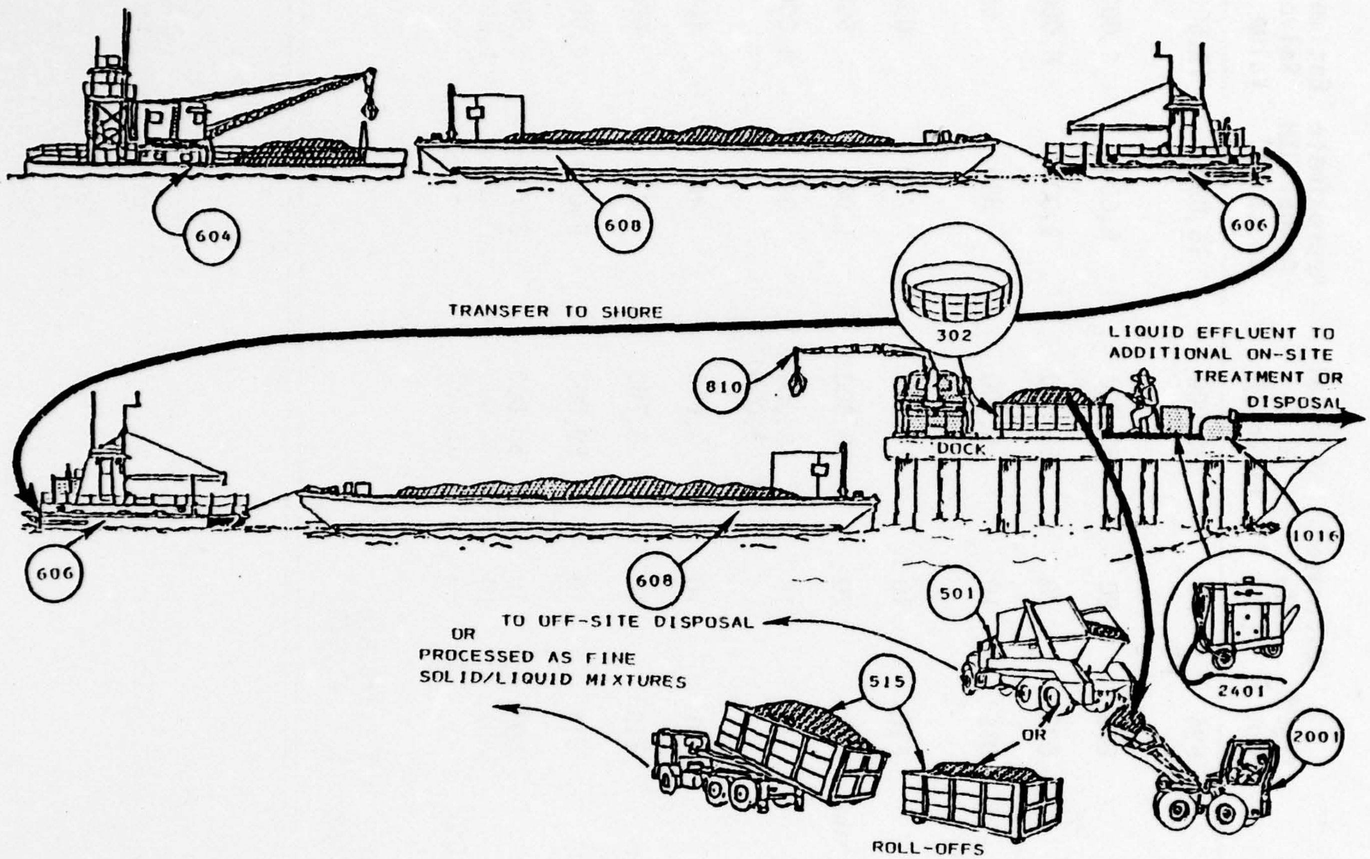

FIGURE 18. SYSTEM 9, SCENARIO M.

TABLE 21. SYSTEM 9: CRITICAL EQUIPMENT ELEMENTS

Qty	Equipment Element	Item* No.	Estimated Life (Yr)	Capital Cost (1978 $)	Approximate Annual O&M Costs ($)	Estimated Salvage Value ($)
1	collection vessel	604	20	390,000	15,000	19,500
1	workboat	606	20	80,000	5,600	4,000
1	barge	608	20	150,000	5,000	8,000
1	centrifugal pump and motor	1016	10	6,300	300	60
1	crane	810	10	12,500	750	600
1	temp. storage tank	302	20	9,500	1,000	500
6	open-top roll-off bins	515	10	18,000 (3,000)†	300	3,000
1	washing equip.	1401	10	3,615	400	180
1	flatbed trailer	513	10	8,700	870	400
1	truck-tractor	514	10	59,000	6,000	4,000
1	dump truck	501	10	50,000	3,700	2,500
1	tractor	2001	10	24,000	2,400	1,200
	contingency (10%)	--	--	81,162	--	--

Life Cycle Cost = $ 1,370,810
Total Annual Cost = $ 41,320

*Appendix D.
†Unit costs.

Approximate Size and Weight of the Equipment--

Table 22 shows the approximate dimensions and weights of each equipment element included in the system. Plans for each element are shown in the indicated figures.

TABLE 22. SYSTEM 9: DIMENSIONS AND WEIGHTS OF CRITICAL EQUIPMENT ELEMENTS

Equipment element	Item no.	L (m)	W (m)	H (m)	D	Weight(kg)	Fig.*
Recovery vessel	604	29.59	10.85	2.13	-	218,450	E-13
Workboat	606	11.73	5.03	1.60	-	31,750	E-15
Barge	608	32.31	7.92	2.59	-	90,710	E-16
Centrifugal pump + motor	1016	1.50	0.45	0.60	-	184	E-21
Tractor	2001	4.57	2.26	3.76	-	4,540	E-32
Wash equipment	1401	1.25	.64	1.18	-	238	E-34
Crane	1810	8.70†	-	10.00†	-	2,110	E-17
Open-top roll-offs	515	6.78	2.24	2.29	-	3,764	E-11
Open-top storage tanks (in envelope)	302	1.2	3.0	1.2	-	2,700	E-2
Dump truck	501	5.1	2.43	1.80	-	2,358	E-7
Flat bed truck	513	13.0	2.64	1.20	-	4,590	E-9
Truck tractor	514	5.98	2.44	2.98	-	19,800	E-10

*For conceptual drawing, see figure indicated, Appendix E.
†Key dimensions: L = lateral reach, H = lift distance.

Transportability by Existing Coast Guard Vessels and Aircraft Capability--

Appendix F describes the dimensions of various cargo holds for Coast Guard aircraft and vessels, and the transportability of the equipment included in System 9.

Transportability by Means Other Than Coast Guard Vessel and Aircraft--

See Appendix F.

Special Requirements--

The limiting element in System 9 is the barge (Item No. 608), which requires towing to the site by either the recovery vessel or a workboat. The crane (Item No. 810) may be mounted on the flatbed truck, provided that the overall height limit is not exceeded.

Specially trained Coast Guard personnel are required for installation and operation of all equipment included in System 9. During simultaneous operation of all equipment elements, it is estimated that a maximum of seven persons is required as crew, including: barge - 2, crane - 1, pumps - 1, storage tanks - 1, truck - 2. Additional support transport may be required for transporting the crew to the field of operation.

Diesel fuel must also be provided for operation of the workboat and crane. Pumps may also be diesel-powered. These units are provided with limited on-board fuel storage. For prolonged operations, a small tank truck may be required for bringing additional fuel to the site.

System 10

System 10 is defined as follows (Figure 19):

> Material is collected from offshore or onshore operations in a manner identical to that described in System 9. The spill mass is predominantly small wood solids, so on-site separation or washing is not warranted. Instead, the material is transferred to a shredder or chipper. The reduced mass is then stored and processed as indicated for fine solids in Scenario G, or is taken to off-site disposal site(s).

As in System 9, two shore-to-off-site transport modes are included in this system. Solids from the chipper or shredder are stockpiled temporarily, or loaded directly into a lined dump, or placed into smaller portable containers, loaded onto flatbed trucks, and transported to an off-site facility.

Critical equipment elements of System 10 are shown in Table 23. The total life cycle and annual costs for the system are $1,717,679 and $50,270, respectively.

Oils Which Can and Cannot Be Handled--

The limiting factor in the handling of oil-contaminated debris is the potential for generating explosive fumes in the chipping or grinding chambers. Debris contaminated with oils from oil Groups II and III (see Appendix A) should present no problem. Debris which is impregnated with large volumes of oils belonging to Groups I, IV, or V, should not be handled by System 10. A safe technique is to de-oil the debris prior to the chipping or grinding (see System 11).

Approximate Quantity of Spill Mass Which Can Be Handled--

Large shredder units can handle between 38 and 76 m^3/hr (50 and 100 yd^3/hr) or between (6.3 and 22.5 t/hr) (7 and 25 tons/hr). Chippers have similar capacities. Based on a 4-day processing operation of 8 hr/day, this would indicate a maximum of more than 1 million m^3 (based on the volumetric estimate) which could be processed during the operation. Other transfer and storage limitations affecting System 10 are discussed under System 9 and indicate that 3,800 m^3 is the limiting volume.

Technical Feasibility of Development Including Critical Elements--

The chipper and grinder recommended for this system are each portable to the site as trailerable units. All other

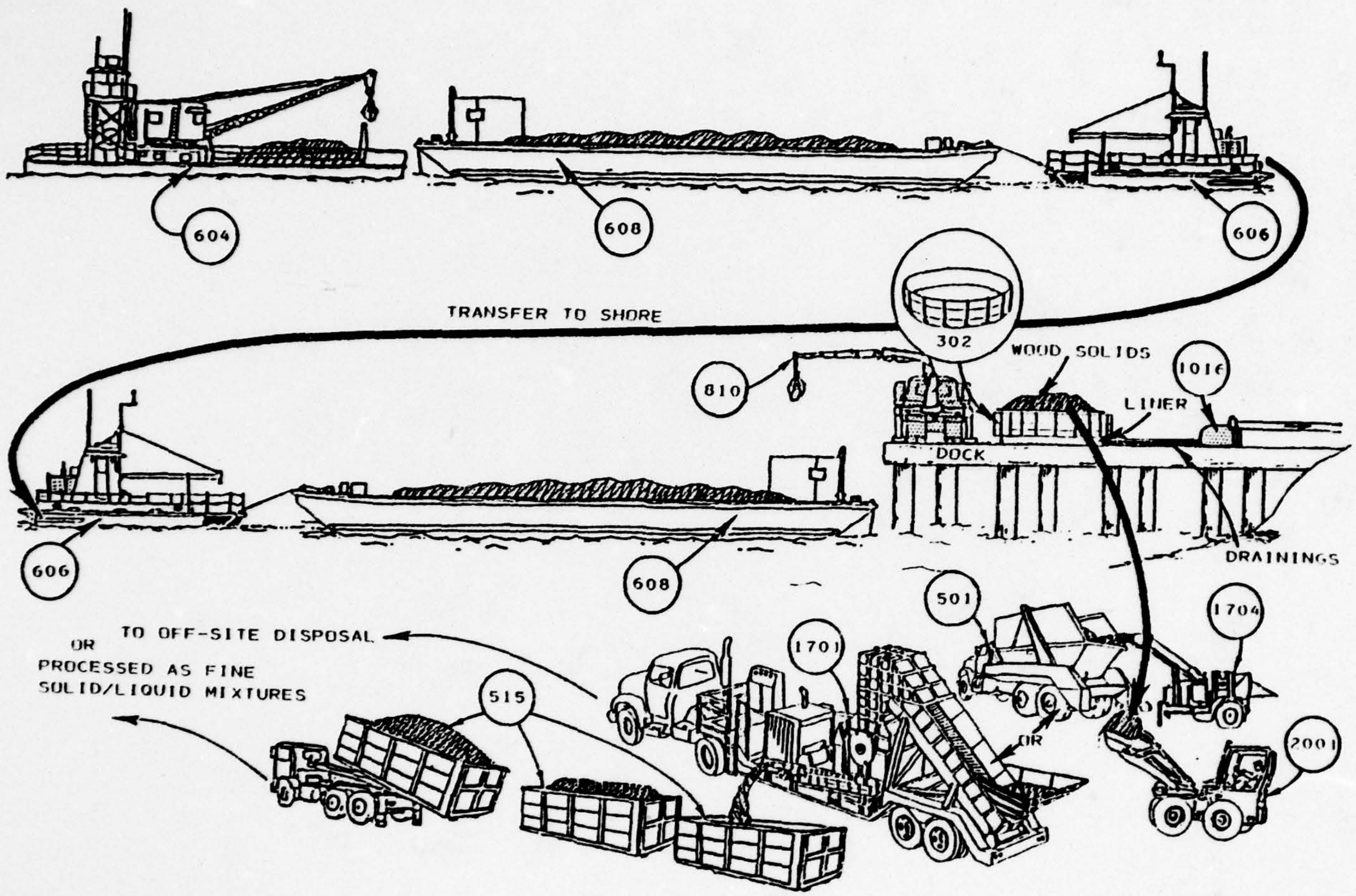

FIGURE 19. SYSTEM 10, SCENARIO M.

TABLE 23. SYSTEM 10: CRITICAL EQUIPMENT ELEMENTS

Qty	Equipment Element	Item No.*	Estimated Life (Yr)	Capital Cost (1978 $)	Approximate Annual O&M Costs ($)	Estimated Salvage Value ($)
1	collection vessel	604	20	390,000	15,000	19,500
1	workboat	606	20	80,000	5,600	4,000
1	barge	608	20	150,000	5,000	8,000
1	shredder	1701	10	50,000	3,700	2,500
1	chipper	1704	10	89,000	5,650	4,500
1	centrifugal pump and motor	1016	10	6,300	300	60
1	crane	810	10	12,500	750	600
1	temp. storage tank	302	20	9,500	1,000	500
6	open-top roll-off bins	515	10	18,000 (3,000)†	300	3,000
1	flatbed trailer	513	10	8,700	870	400
1	truck-tractor	514	10	59,000	6,000	4,000
1	dump truck	501	10	50,000	3,700	2,500
1	tractor	2001	10	24,000	2,400	1,200
	contingency (10%)	--	--	94,700	--	--

Life Cycle Cost = $ 1,717,679
Total Annual Cost = $ 50,270

*Appendix D.
†Unit costs.

equipment included in this system is also included in System 9. All critical elements are available on the market and may be readily assembled into a well-defined system for transport to a recovery site.

Environmental Impacts of the System Operations and Mitigation Measures--

See System 9.

Approximate Size and Weight of the Equipment--

Table 24 shows the approximate dimensions and weights of each equipment element for System 10. Plans for each element are shown in the indicated figures.

Transportability by Existing Coast Guard Vessels and Aircraft Capability--

Appendix E describes the dimensions of various cargo holds for Coast Guard aircraft and vessels, and the transportability of the equipment included in System 10.

TABLE 24. SYSTEM 10: DIMENSIONS AND WEIGHTS OF CRITICAL EQUIPMENT ELEMENTS

Equipment Element	Item No.	L (m)	W (m)	H (m)	Weight (kg)	Fig.*
Recovery vessel	604	29.59	10.85	2.13	218,450	E-13
Workboat	606	11.73	5.03	1.60	31,750	E-15
Barge	608	32.31	7.92	2.59	70,710	E-16
Centrifugal pump and motor	1016	1.50	0.45	0.60	184	E-21
Crane	810	8.70†	-	10.00†	2,110	E-17
Open-top roll-offs	515	6.78	2.24	2.29	3,764	E-11
Temporary storage tanks (in envelope)	302	1.2	3.0	1.2	2,700	E-2
Shredder	1701	1.57	1.52	1.42	5,000	E-28
Chipper	1704	3.96	2.13	1.83	4,500	E-29
Flat bed truck	513	13.0	2.64	1.20	4,590	E-9
Dump truck	501	5.1	2.43	1.80	2,358	E-7
Truck-tractor	514	5.98	2.44	2.98	19,800	E-10
Tractor	2001	4.57	2.26	3.76	4,540	E-32

*For conceptual drawing, see figure number indicated, Appendix E.
†Key dimensions: L = lateral reach, H = lift distance.

Transportability by Means Other Than Coast Guard Vessel and Aircraft--

See Appendix F.

Sepcial Requirements--

The limiting elements in System 10 are the barge, 608, towable by workboat, and the crane, 810, transportable by truck, as previously discussed in Special Requirements for Systems 8 and 9. Additional items (shredder, 1701, and chipper, 1704) are best implemented as truck-mounted systems.

Specially trained Coast Guard personnel are required for installation and operation of all equipment included in System 10. During simultaneous operation of all equipment elements, it is estimated that a maximum of nine persons is required as crew for: barge - 2, crane - 1, pumps - 1, tanks - 1, truck - 2, shredder or chipper - 2. Additional support may be required for transporting the crew to the field of operation.

Diesel fuel must also be provided for operation of the chipper, 1704, shredder, 1701, workboat, 606, and crane, 810. These units are provided with limited on-board fuel storage. For prolonged operations, a small tank truck may be required for bringing additional fuel to the site.

<u>System 11</u>

System 11 is defined as follows (Figure 20):

> This system is the composite of the two previous systems in that, following onshore washing and draining (System 9), the wood solids are separated out and submitted to shredding or chipping operations (System 10).

Table 25 shows the critical elements for System 11. The total life cycle and annual costs are $2,615,064 and $179,265, respectively.

Oils Which Can and Cannot Be Handled--

As indicated in the discussion of System 10, washing will improve the safety factor for grinding or chipping debris which has been impregnated with oils of the more volatile groups (I, IV, and V - see Appendix A). Therefore, with proper washing of spill debris, this system is applicable to all oils.

Approximate Quantity of Spill Mass Which Can Be Handled--

The limiting process volume is the same as for Systems 9 and 10, i.e., about 3,800 m^3.

Technical Feasibility of Development Including Critical Elements--

See Systems 9 and 10.

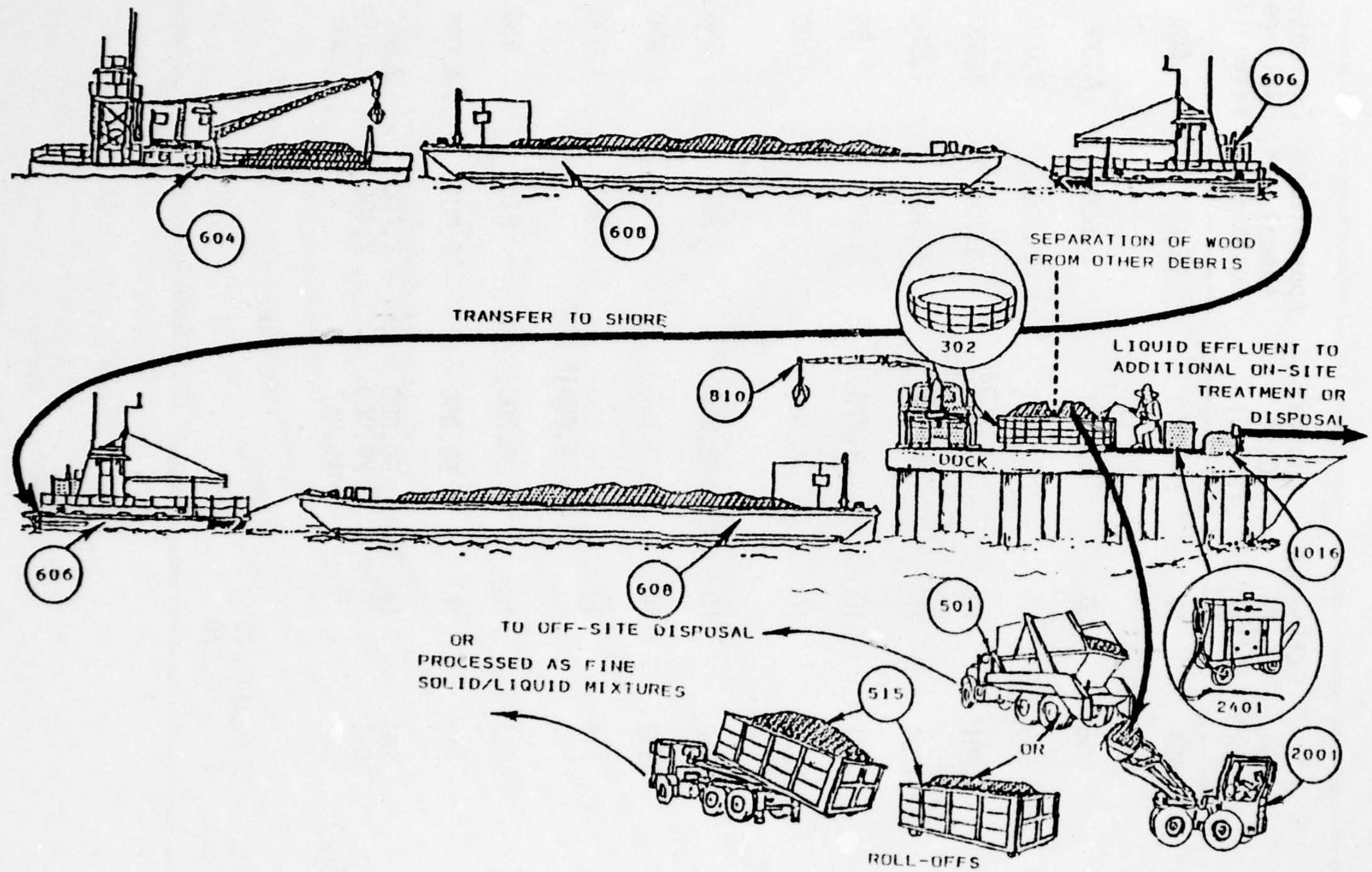

FIGURE 20. SYSTEM 11, SCENARIO M.

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DISPOSAL SYSTEMS AND TECHNIQUES FOR OIL AND HAZARDOUS CHEMICALS--ETC(U)
FEB 79 D E ROSS, W G HANSEN, J G KUYKENDALL DOT-CG-71044-A
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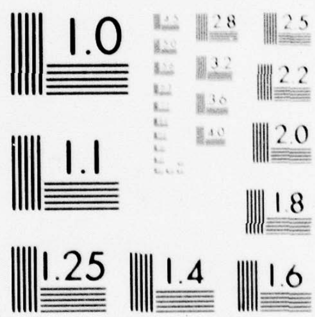

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

TABLE 25. SYSTEM 11: CRITICAL EQUIPMENT ELEMENTS

Qty	Equipment Element	Item No.*	Estimated Life (Yr)	Capital Cost (1978 $)	Approximate Annual O&M Costs ($)	Estimated Salvage Value ($)
1	collection vessel	604	20	390,000	15,000	19,500
1	workboat	606	20	80,000	5,600	4,000
1	barge	608	20	150,000	5,000	8,000
1	shredder	1701	10	50,000	3,700	2,500
1	chipper	1704	10	89,000	5,650	4,500
1	washing equip.	2401	10	3,615	400	180
1	centrifugal pump and motor	1016	10	6,300	300	60
1	crane	810	10	12,500	750	600
1	open-top tank	302	20	9,500	1,000	500
6	open-top roll-off bins	515	10	18,000 (3,000)†	300	3,000
1	flatbed trailer	513	10	8,700	870	400
1	truck-tractor	514	10	59,000	6,000	4,000
1	dump truck	501	10	50,000	3,700	2,500
1	tractor	2001	10	24,000	2,400	1,200
	contingency (10%)	--	--	95,062	--	--

Life Cycle Cost = $ 1,584,622
Total Annual Cost = $ 50,670

*Appendix D.
†Unit costs.

Environmental Impacts of the System Operations and Mitigation Measures--
See System 9.

Approximate Size and Weight of the Equipment--
Table 26 shows the approximate dimensions and weights of each equipment element for System 11. Plans for each element are shown in the indicated figures.

Transportability by Existing Coast Guard Vessel and Aircraft Capability--
See System 10.

Transportability by Means Other Than Coast Guard Vessel and Aircraft--
See System 10.

Special Requirements--
See System 10.

TABLE 26. SYSTEM 11: DIMENSIONS AND WEIGHTS OF CRITICAL EQUIPMENT ELEMENTS

Equipment element	Item no.	L (m)	W (m)	H (m)	D (m)	Weight (kg)	Fig.*
Recovery vessel	604	29.59	10.85	2.13		218,450	E-13
Workboat	606	11.73	5.03	1.60		31,750	E-15
Barge	608	32.31	7.92	2.59		70,710	E-16
Centrifugal pump and motor	1016	1.50	0.45	0.60		184	E-21
Crane	810	8.70†	--	10.00†		2,110	E-17
Conveyor	901	--	Var.	--		Var.	E-18
Temporary storage tanks (in envelope)	302	1.2	3.0	1.2	0.9-1.2	2,700	E-2
Chipper	1712	4.1	2.4	2.8		4,411	E-30
Dump truck	501	5.1	2.43	1.80		2,358	E-7

*For conceptual drawing, see figure number indicated, Appendix E.
†Key dimensions: L = lateral reach, H = lift distance.

SCENARIO N - OIL/ORGANIC SOLIDS MIX, STORMY WEATHER, COLD AIR TEMPERATURE

Scenario N is defined as follows:

Oil mixed with large amounts of organic solids (seaweed, storm debris, organic sorbents, etc.), stormy weather, cold air temperature.

The oils considered in this scenario are described in Appendix A. The solid debris materials are the same as those described in Scenario M.

The climatic conditions of Scenario N can cause considerable ice formation on the solids during recovery. Experience has shown (Buzzard's Bay, Hudson Bay) that ice is, in fact, recovered with the organic solids and does not thaw until the last pre-processing step in the spill mass recovery exercise. The ice is also more likely to be porous or granular than smooth. The total capability of the iced solids to absorb spilled fluid may be as much as double that of solids collected in warm weather. Yet the increased amount of clean ice collected during recovery of contaminated ice may result in larger debris volumes.

As the total recovered debris ranges from roughly one-half to 1.5 times that collected in Scenario M, the recovery alone should require from approximately 10 or more days, as opposed to the 7-day period required for Scenario M.

Separation at the pickup site on board the workboats or barge(s), on the other hand, will likely be a more lengthy process, due to the higher viscosity of the oil at freezing temperatures (10,000 as opposed to 200 centistokes). Heaters may be employed to speed up this phase of the recovery effort.

Application of Systems 8 and 10 will be essentially identical, in all other respects, to their counterparts, discussed under Scenario M.

Systems 9 and 11 (under Scenario N) are excluded from consideration because they involve washing activities deemed infeasible in freezing conditions.

SCENARIO S - OIL SOAKING LARGE SOLIDS, CALM WEATHER, WARM AIR TEMPERATURE

Scenario S is defined as follows:

> Oil soaking primarily large solids (pieces of dock, vessels, trees, etc.), calm weather, warm air temperature.

The solid debris material of this scenario requires special machinery for lifting and is therefore different from the solids defined by preceeding scenarios, which may be collected in small volumes by one man. Typically, the large objects are metallic, such as pieces of grounded or destroyed vessels, or organic, such as logs, plastic sheeting, or debris from wooden structures.

The oils considered in this scenario include the five groups defined in Appendix A. Through interviews with individuals involved in past work with large spill debris, it is noted that oil will usually wet the outer surface of objects without appreciably contaminating the inner volume. Exceptions include dry, rotted logs, the inner tissues of which tend to act as sponges and draw the oils into the interior. In general, objects with a matrix capable of soaking up oil will do so unless the interior is already occupied by another fluid, such as water.

The warm air temperature defined by Scenario S does not impact the handling or processing of debris directly. However, chipping of organic objects, or compaction of metallic objects by cutting torch, is not considered safe in the presence of the highly volatile oils defined by Groups I, IV, and V. Under such circumstances, the oils must first be washed off the debris to such an extent that they no longer present an explosion hazard.

Physical separation of excess oils by gravity or by washing will yield a waste fluid mixture of oils and water similar to that defined by Scenario A. The on-site transfer, storage, treatment or disposal of spill masses for that scenario are therefore directly applicable to debris rinsings. Where detergents are used, the rinsings will be heavily emulsified. On-site demulsification and separation may be used, or the fluids can be shipped directly to off-site processing. Consideration of on-site or off-site land disposal should include an understanding of the toxicity and mobility of the cutting stock or detergents once they are released to a soil environment.

Crushing, splitting, and chipping of large organic debris will eventually yield a collection of chips or fines mixed with oil. Such a mixture resembles oil-debris mixtures defined by Scenarios G or A, and may be handled on site or transported for off-site processing as indicated for those scenarios. It may also be taken directly to on-site or contracted disposal locations.

General Systems

Figure 21 shows the general on-site methods and equipment categories which may be applied to the various types of oil-soaked debris defined by Scenario S, and to other scenarios involving large solids. Upon primary recovery, the object is usually placed on the deck of the primary recovery vessel itself, or on a nearby barge or work vessel tending the primary recovery craft. Onshore recovery is accomplished in the same manner using a mobile crane and loading the contaminated object onto a truck bed or railcar.

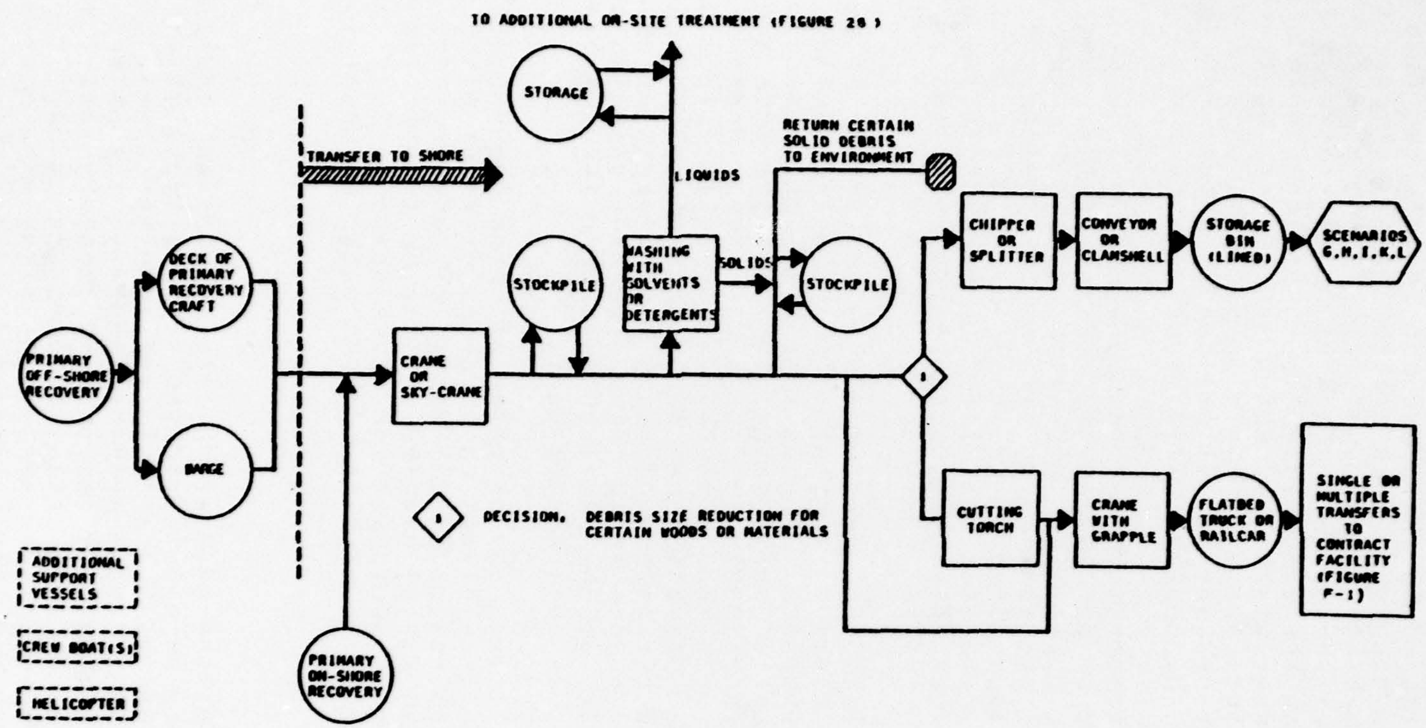

FIGURE 21. SCENARIOS S THROUGH X: GENERAL EXISTING SYSTEMS FOR STORAGE, TRANSFER, TRANSPORT AND ON-SITE TREATMENT OF RECOVERED SPILL MASS.

Once the object is present at the onshore site (lifted ashore by a crane or helicopter), it may be washed, cut up, or chipped to reduce the problem of transport to off-site treatment or disposal. In certain instances, natural objects, such as beach logs, may be left at the shoreline site if they can be sufficiently decontaminated by washing.

System 12

A specific disposal system for large wood solids, as defined by Scenario S, is described as follows (Figure 22):

> Large wood solids from off-shore recovery are placed on the deck of the primary recovery vessel (PRV), or onto the deck of a nearby barge by means of a crane and grapple that are fixed to the deck of the recovery vessel. The barge is towed by the recovery craft or by another workboat. Once transferred to shore, the large debris is off loaded by a mobile crane and stockpiled on a liner to prevent soil contamination.
>
> The large object(s) are then washed with solvents or detergents to remove adhering spilled fluids. The liquid washings are transferred to additional on-site treatment or disposal, as applied to fluids defined by Scenario A.
>
> Some solid debris, particularly natural materials such as logs, may be returned to the environment after they are sufficiently cleaned. Otherwise, debris is stockpiled and processed by a chipper and/or splitter. The resulting reduced debris is then moved by a conveyor or crane with a clamshell attachment to temporary storage in a lined storage bin to await transfer to off-site processing, or to further on-site treatment/disposal as described for Scenarios G or M.

Critical equipment elements of the system are shown in Table 27. The total life cycle cost and annual cost are $1,079,006 and $42,160, respectively.

Oils Which Can and Cannot Be Handled--

Processing of large wooden debris objects coated with any of the oils included in the five oil groups described in Appendix A, is possible using System 12. Heavier oils, particularly those in Group III and the crudes, may require a solvent cutting stock to be applied during washing. Diesel fuel is often used for this purpose. However, when hydrocarbon solvents are used to wash, the washings must be carefully contained and processed without release to the environment.

If sufficient washing does not precede the chipping process, the more volatile oils for Group I (jet fuels), and especially

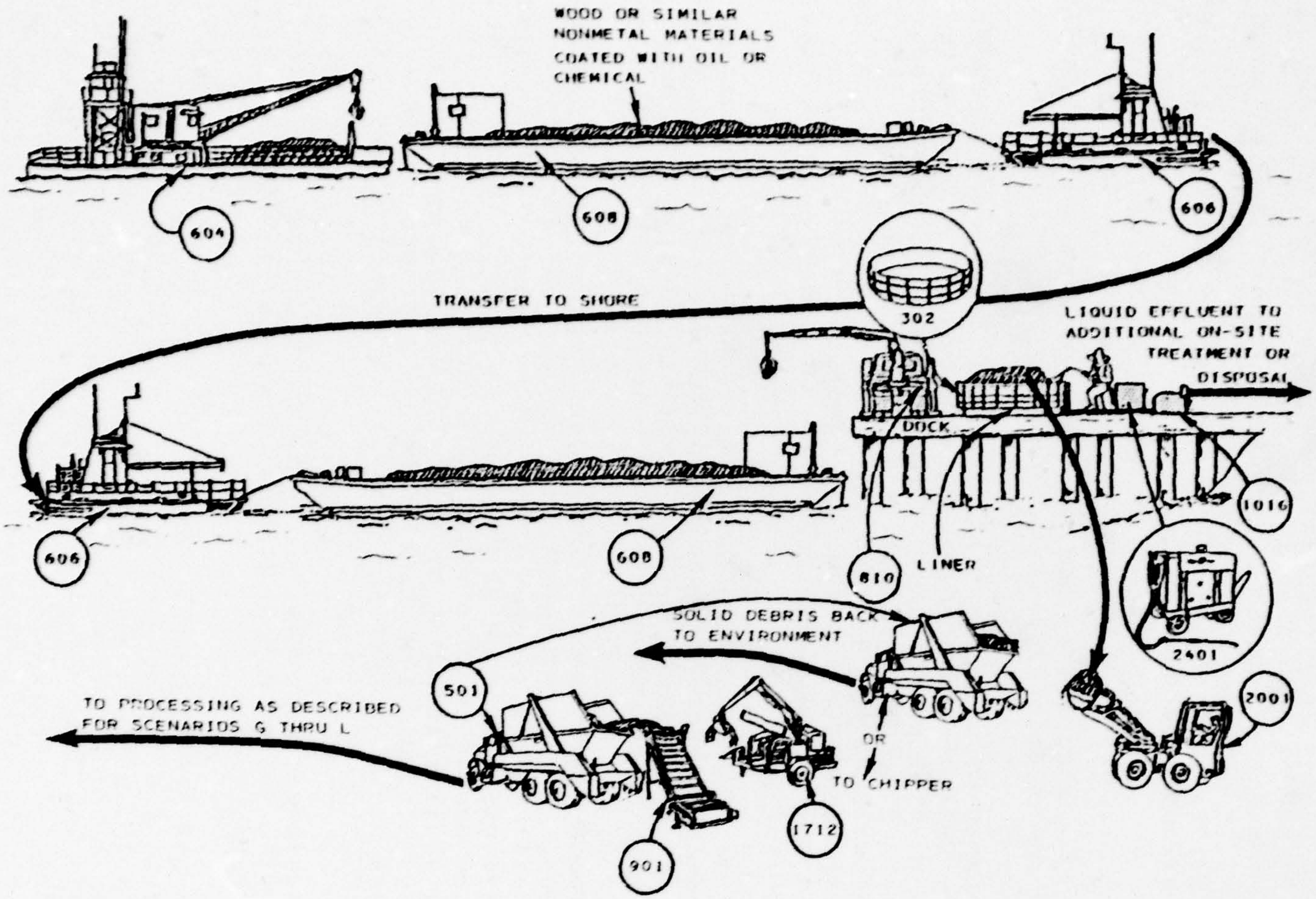

FIGURE 22. SYSTEM 12, SCENARIO S.

TABLE 27. SYSTEM 12: CRITICAL EQUIPMENT ELEMENTS

Qty	Equipment Element	Item No.*	Estimated Life (Yr)	Capital Cost (1978 $)	Approximate Annual O&M Costs ($)	Estimated Salvage Value ($)
1	workboat	602	20	168,000	22,800	8,400
1	barge	608	20	150,000	5,000	8,000
1	liner with drainage control	104	2	540	- 0 -	- 0 -
1	crane (at sea)	801	10	30,000	3,000	1,500
1	crane (dock side)	810	10	12,500	750	600
1	washing equip.	2401	10	3,615	400	180
1	chipper	1712	10	32,000	2,800	1,600
1	conveyor	901	5	13,000	710	650
1	dump truck	501	10	50,000	3,700	2,500
1	tractor	2001	10	24,000	2,400	1,200
	contingency (10%)	--	--	49,626	--	--

Life Cycle Cost = $ 1,079,006
Total Annual Cost = $ 42,162

*Appendix D.

Group IV (JP-4) and V (coal tar), can generate an explosion hazard in the chipper chamber. This system is therefore best suited for dealing with oil Groups II and III, but may be applied to groups I, IV, and V if preceded by careful washing to remove all residual volatiles.

Approximate Quantity of Spill Mass Which Can Be Handled--

Maximum tonnage of the solid objects which can be recovered is limited by the storage capability of the workboat and the lift capacity of the dock-mounted crane. Pieces of wood debris such as logs, in excess of 14 inches in diameter, cannot be chipped without prior splitting. The workboat has a 5-ton debris transport capability. The crane is also limited to about 5 tons lifting capabilities within a limited lifting radius (less than 7 m).

It is not anticipated that the fluid rinsings or reduced chipped solids from the debris defined by this scenario will exceed the volumetric capabilities for treatment, as defined for Scenarios A, G, or M.

Technical Feasibility of Development Including Critical Elements--

The general plan of the described system has been documented through interviews with various port authorities experienced in handling logs and other large wooden debris in harbor waters. All critical elements for this system are available on the market, and may be readily assembled into a well-defined, portable system for transport to the recovery site. The crane and grapple are available as a truck-mountable unit. The only nonportable element is the workboat. The workboat may be replaced by a smaller scow-workboat combination, or large floating objects may be towed in the water by a workboat.

In certain instances, debris may be lifted out of the water and carried to shore by a helicopter. The cost of including such a capability is not warranted if the helicopter is to be used for this intermittent purpose only.

Environmental Impacts of System Operation and Mitigation Measures--

System 12 has several points in the flow of debris handling where environmental impacts may occur:

- At water-to-shore transfer of the oil-soaked debris
- From lack of containment of rinsings from the debris-washing operation.
- By return of inadequately de-oiled debris to the environment.

The transport and use of the heavy portable equipment at sensitive shoreline areas may also result in damage to plant life and the disturbance of soil surfaces.

The potential for further water contamination by dripping from debris transfers may be minimized by placing a small oil-containment boom around the debris-laden vessel and under the "path-of-swing" described by the crane boom. Drippings can then be recovered using a small volume of sorbent materials. Containment booms and contractor services are usually available at or near the transfer location to be used in containment of oils at the primary spill site.

Containment of rinsings from the debris-washing operation is a significant factor in avoiding soil contamination at the washing operation. Irregular or jagged debris can easily cut a hole in the liner, resulting in substantial leakage. Where heavy objects are involved, a bed of sand or other padding material may be placed on the liner to provide a cushion and prevent puncture. Sorbent materials should also be kept on hand to contain accidental release of rinsings.

Prior to returning washed natural debris (e.g., beach logs) to the environment, a careful check should be made to be sure that further environmental contamination is prevented. With oils, this can be done by cutting a sample of the wood which includes outer and inner tissues, and soaking it in a small volume of water. If the surface of the water acquires a substantial sheen, then the wood is still releasing oils and is not suitable for release. Further processing is required.

Approximate Size and Weight of the Equipment--

Table 28 shows the approximate dimensions and weight of each equipment element for System 12. Plans for each element are shown in the indicated figures.

Transportability of Existing Coast Guard Vessels and Aircraft Capability--

Appendix F describes the dimensions of various cargo holds for Coast Guard aircraft and vessels, and the transportability of the equipment included in disposal System 12.

TABLE 28. SYSTEM 12: DIMENSIONS AND WEIGHTS OF CRITICAL EQUIPMENT ELEMENTS

Equipment Element	Item No.	L (m)	W (m)	H (m)	D (m)	Weight(kg)	Figure*
workboat	602	12.19	4.47	0.61	-	89,110	
barge	608	32.31	7.92	2.59	-	90,710	E-16
liner	104	-	var.	-	-	-	
crane	801	7.62+	-	9.75+	-	25,000	
crane	810	8.70	-	10.00+	-	2,110	E-17
washing equipment	2401	1.25	.64	1.18		238	E-34
chipper	1712	4.1	2.4	2.9		4,411	E-30
conveyor	901	-	var.	-	0.9-1.2	var.	E-18
dump truck	501	5.1	2.43	1.80	-	2,358	E-7
tractor	2001	4.57	2.26	3.76	-	4,540	E-32

* For conceptual drawing, see Appendix E.
+ Key dimensions: L = lateral reach, H = lift distance.

Transportability by Means Other Than Coast Guard Vessel and Aircraft--
See Appendix F.

Special Requirements--
The limiting element in System 12 is the truck-mounted crane which cannot be transported to the field site by sea or air. The lined dump truck may also be limiting, yet it is secondary to the processing operation and is used only for transferring the solid debris to an off-site location. Timing is therefore not a significant factor, and arrangements can be made for temporary storage or transport by means other than truck (e.g., loading onto Coast Guard transport craft). Therefore, on-site lifting capabilities may be provided by a barge-mounted crane, or by a skycrane helicopter.

Specially trained Coast Guard personnel are required for installation and operation of all equipment included in System 12. During simultaneous operation of all equipment elements, it is estimated that a maximum of seven persons is required as crew, including a workboat crew of 2, one crane operator, a chipper operator, one conveyor operator, and two drivers/pilots. Additional support may be required for transporting the crew to the field of operation.

Diesel fuel must also be provided for operation of the chipper, conveyor drive, crane system, and workboats. All units are provided with limited on-board fuel storage. For prolonged operations, a small tank truck may be required for bringing additional fuel to the site.

System 13

System 13 is similar to disposal System 12, in that it is designed to transport and process large debris objects as described by Scenario S. The primary difference is that metallic objects, such as pieces of a ship's hull, are involved (Figure 23):

> Large metallic solids are recovered from off shore and placed on the deck of a primary recovery vessel (PRV), or onto the deck of a nearby barge by means of a crane and grapple fixed to the deck of the recovery vessel. The barge is towed by the recovery craft or by another workboat. Once transferred to shore, the large debris is off loaded by a mobile crane and stockpiled on a liner to prevent soil contamination.
>
> The large object(s) are then washed with solvents or detergents to remove adhering spilled fluids. The liquid washings are transferred to additional on-site treatment or disposal (see "On-site Disposal"), as applied to fluids

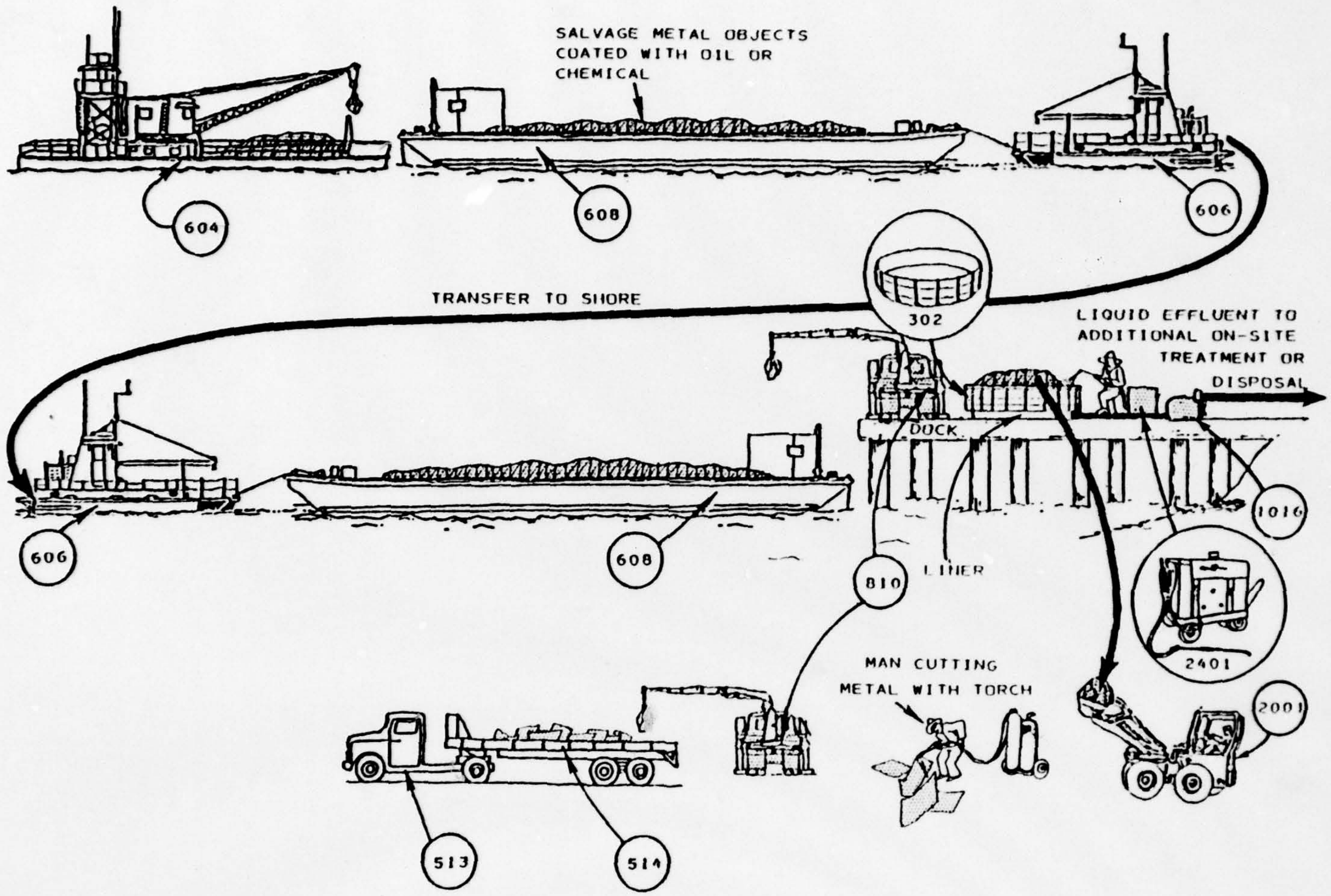

FIGURE 23. SYSTEM 13, SCENARIO S.

defined by Scenario A. The metallic debris is then stockpiled and later loaded on a flatbed truck for transport to an off-site salvage or disposal facility. If the object is composed of workable metals, it may be reduced prior to transport by use of a cutting torch.

Critical equipment elements of the system are similar to the previously described System 12, except that the chipper and conveyor (for the chipper discharge) are replaced by a one- or two-man team equipped with cutting torches. Equipment elements for System 13 are shown in Table 29. Total life cycle and annual costs for System 13 are $1,004,644 and $42,020, respectively.

Oils Which Can and Cannot Be Handled--

Limitations on the processing of large metallic objects, coated with any of the oils included in the five oil groups described in Appendix A, are similar to those discussed for System 12. If cutting torches are to be used at the processing site, the more volatile oils from Group I, and especially Groups IV (JP-4) and V (coal tar), can present an explosion hazard if the objects are not thoroughly decontaminated. In-field torching of closed vessels and tanks should not be conducted unless the contents are nonvolatile fire-retardent, or in other ways deemed safe from the standpoint of explosion hazard. This system is best suited for dealing with oil Groups II and III, but may be applied to Groups I, IV, and V with careful control of residual volatiles.

Approximate Quantity of Spill Mass Which Can Be Handled--

The maximum weight of the solid objects which can be recovered by this system is the same as that defined for System 12; 4.5 tonnes (5 tons). It is not anticipated that the fluid rinsings from the washing process included in this system will exceed the volumetric capabilities for treatment as defined for Scenarios A, G, or M.

Technical Feasibility of Development Including Critical Elements--

All critical elements for this system are available on the market and may be readily assembled into a well-defined portable system for transport to the recovery site. The crane and grapple are available as a truck-mountable unit. The only nonportable element is the workboat. The workboat may be replaced by a smaller scow-workboat combination. Since large metallic objects will usually sink (unless provided with bulwarks), most recovery and transfer operations will usually occur at near-shore locations. It is therefore probable that the primary craft may transport the objects directly to shore without transferring them to shuttle barges or support vessels. In certain instances, debris may be lifted out of the water and carried to shore by a helicopter. The inclusion of a helicopter in System 13 is not warranted if the helicopter is to be used for this intermittent purpose only.

TABLE 29. SYSTEM 13: CRITICAL EQUIPMENT ELEMENTS

Qty	Equipment Element	Item No.*	Estimated Life (Yr)	Capital Cost (1978 $)	Approximate Annual O&M Costs ($)	Estimated Salvage Value ($)
1	workboat	602	20	168,000	22,800	8,400
1	barge	608	20	150,000	5,000	8,000
1	liner with drainage control	104	2	540	- 0 -	- 0 -
1	crane	801	10	30,000	3,000	1,500
1	crane	810	10	12,500	750	600
1	washing equip.	2401	10	3,615	400	180
1	flatbed trailer	513	10	8,700	870	400
1	truck-tractor	514	10	59,000	6,000	4,000
1	tractor	2001	10	24,000	2,400	1,200
1	cutting torches	--	5	2,000	200	10
	contingency (10%)	--	--	47,096	--	--

Life Cycle Cost = $ 1,004,644
Total Annual Cost = $ 42,020

*Appendix D.

Environmental Impacts of System Operations and Mitigation Measures--

System 13 has two points in the debris handling process similar to System 12 where environmental impacts may occur:

- At water-to-shore transfer of the oil-soaked debris
- From lack of containment of rinsings from the debris-washing operation.

Since the metal objects will probably be removed to off-site salvage, rather than abandoned at the site, the return of inadequately de-oiled debris to the environment should not be a problem.

Steps for mitigation of the potential impacts are similar to those called for in System 12:

- Provide a containment boom around the debris transport vessel and transfer operations
- Provide for cushioning of irregular objects to avoid puncture of liners
- Provide sorbent materials for recovery of released oils.

Approximate Size and Weight of the Equipment--

Table 30 shows the approximate dimensions and weights of each equipment element for System 13. Plans for each element are shown in the indicated figures.

TABLE 30. SYSTEM 13: DIMENSIONS AND WEIGHTS OF CRITICAL EQUIPMENT ELEMENTS

Equipment Element	Item No.	L (m)	W (m)	H (m)	Weight (kg)	Figure*
recovery vessel	602	12.19	4.47	0.61	89,110	
barge	608	32.31	7.92	2.59	90,710	E-16
liner w/drainage control	104	-	var.	-	-	
pump	1016	1.50	0.45	0.60	184	E-21
crane	801	7.62†	-	9.75†	∿5,000	
crane	810	8.70†	-	10.00†	2,110	E-17
washing equipment	2401	1.25	.64	1.18	238	E-34
flatbed trailer	513	13.0	2.64	1.20	4,590	E-9
truck-tractor	514	5.98	2.44	2.98	19,800	E-10
tractor	2001	4.57	2.26	3.76	4,540	E-32

*For conceptual drawing, see figure number indicated, Appendix E.
†Key dimensions: L = lateral reach, H = lift distance.

Transportability by Existing Coast Guard Vessel and Aircraft Capability--

Appendix F describes the dimensions of various cargo holds for Coast Guard vessels and aircraft, and the transportability of equipment included in System 13.

Transportability by Means Other Than Coast Guard Vessel and Aircraft--

See Appendix F.

Special Requirements--

The limiting element in System 13 is the same as that for System 12, the truck-mounted crane, which cannot be transported to the field site by sea or air. The flatbed truck may also be limiting, yet it is secondary to the processing operation and used only for transferring the solid debris to an off-site location. On-site lifting capabilities may be provided instead by a barge-mounted crane or by a skycrane helicopter.

Specially trained personnel are required for operation of all the equipment elements included in System 13. During simultaneous operation of all elements, it is estimated that a maximum crew of six persons is required. This includes a workboat crew of two, one crane operator, one welder, and two drivers/pilots.

Diesel fuel is required for operation of the crane system and workboats, although each has sufficient fuel tank capacity for even extended operations.

SCENARIO T - OIL SOAKING LARGE SOLIDS, STORMY WEATHER, COLD AIR TEMPERATURE

Scenario T is defined as follows:

> Oil primary soaking large solids, stormy weather, cold air temperature.

The solid debris materials and oils considered in this scenario are identical to those described for the preceding Scenario S.

The environmental conditions of stormy weather and cold air temperature (less than 0°C) distinguish this scenario from Scenario S. Systems 12 and 13, described for Scenario S, may be applied under these environmental conditions with specific modifications. The chipping of organic objects or reduction of metallic objects by cutting torch are still feasible. Washing to remove adhering oils from the objects may be made difficult due to the colder air temperature. The washing step may therefore be omitted, and contaminated debris transferred directly to off-site processing or disposal without being reduced.

Where crushing, splitting, or chipping of large organic debris is deemed feasible, the resulting debris (chips or fines mixed with oil) will resemble oil/debris mixtures defined by Scenarios G or M, and may be handled on-site or transported to off-site processing, as indicated for those scenarios.

ON-SITE TREATMENT OF FLUIDS

In previously described scenarios, fluids separated from the spill mass become candidates for further on-site treatment or disposal. Scenarios A, G, M, and S each generate one of two types of liquid effluent.

- Aqueous fluids slightly contaminated with oils
- Oils contaminated with water.

Figure 24 shows how these fluids are received from on-site recovery and transfer, as described in Scenario A (concentrated oil spill masses), or from processing of spill masses described by Scenarios G or S (effluents from on-site treatment described for those scenarios).

In treatment of spill masses collected and transferred under Scenario A, the fluids are pumped via optional temporary storage and demulsification equipment to an oil/water separator. The concentrated oils are then transferred into drums on pallets or portable tanks. The drums or tanks are then loaded by crane onto flatbed trucks, or pumped out by a vacuum truck or tank truck for transfer to off-site processing or disposal.

The aqueous effluent from the oil/water separation process is then discharged to the environment (if highly purified), or passed to other components for further on-site treatment or disposal.

Options for on-site treatment include chemical or biological treatment by portable package units, or processing by ultrafiltration. Liquid effluents from these "polishing" treatment steps are discharged back to the watercourse. Any generated solids or sludges may be dewatered and transported to off-site processing/disposal, or disposed of on site.

On-site disposal includes incineration of concentrated oils (from the oil/water separator) in a portable incinerator, or on-site burial or land cultivation. The latter is applicable to concentrated or dilute process fluids. Four specific on-site treatment systems, identified as OS-1, OS-2, OS-3, and OS-4, are described below:

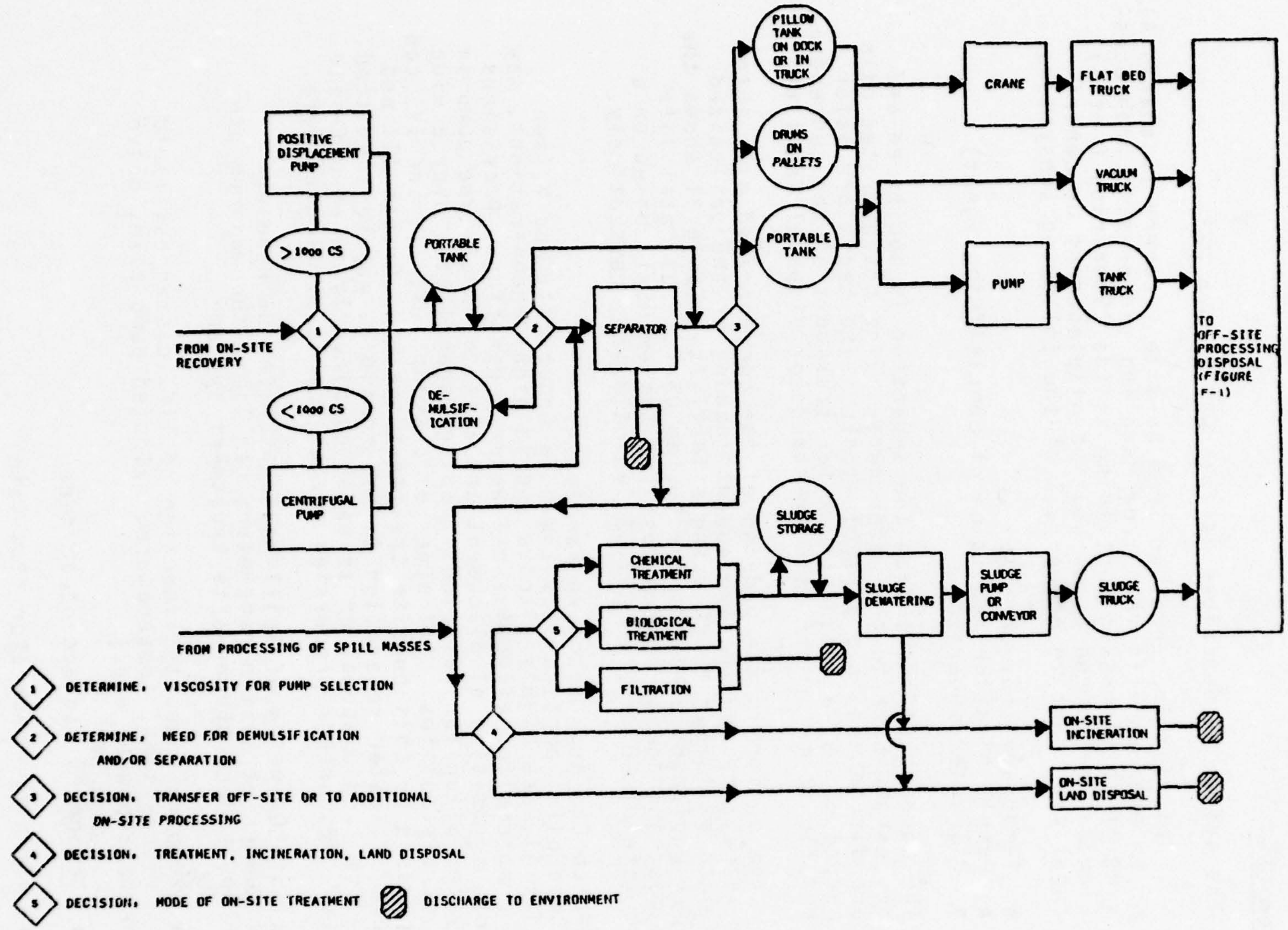

FIGURE 24. SCENARIOS A THROUGH F. GENERAL EXISTING SYSTEMS FOR ON-SITE TREATMENT.

System OS-1

The system is described as follows (Figure 25):

Liquids are received from on-site recovery (Scenario A), or as process effluents from handling and on-site preprocessing of spill masses containing solids (Scenarios G or S). Liquids are pumped by a positive displacement or centrifugal-type pump to one or all of the following subsystems:

- Temporary storage tank
- Demulsification (addition of demulsifying agent)
- Oil/water separator.

The aqueous effluent from the separator is monitored and discharged back to the watercourse. The concentrated oils are discharged into portable tanks. The tanks are later pumped out by a vacuum truck for transport of the concentrated fluids to an off-site treatment or disposal facility.

One system option is the pumping of the concentrated oils into drums on pallets, and the subsequent loading of the palletized drums onto a flatbed truck using a forklift. Table 31 shows the critical equipment elements for System OS-1. The total life cycle cost and annual system cost for System OS-1, based on a system life of 20 yr are $630,525 and $23,180, respectively.

Oils Which Can and Cannot Be Handled--

Some oils, particularly those in Groups III and V (see Appendix A), are highly viscous and, in high concentrations, may cause problems for effective oil/water separation. Provisions for both a positive displacement and a centrifugal-type pump in the system allow for efficient pumping capabilities over a wide range of viscosities. All other oils Groups (I, II, and IV) can be processed by this on-site treatment system. Groups III and V, where oil/water separation is not feasible, may be submitted to on-site land disposal or transported directly to an off-site facility, if further processing capability is available there.

Approximate Quantity of Spill-Mass Which Can Be Handled--

A number of system parameters can limit the maximum process flow through the on-site treatment system:

- Pumping capacity (function of lift distances, fluid viscosities, temperature, selected pump size, drive horsepower, etc.)

- Temporary storage capacities

- Oil/water separator flow rate

- Rate of transfer of system effluents to other systems or off-site facility.

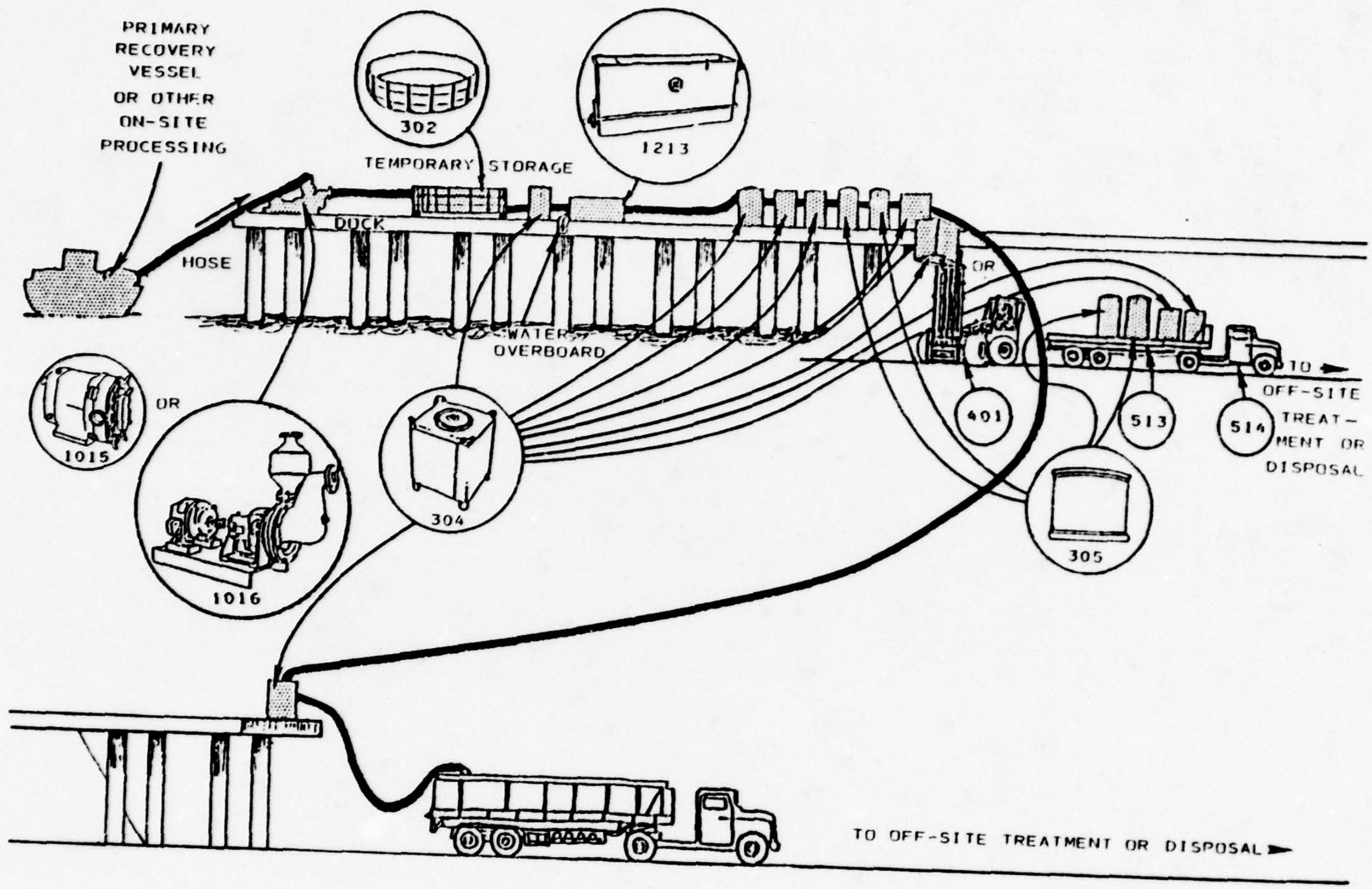

FIGURE 25. SYSTEM OS-1.

TABLE 31. SYSTEM OS-1: CRITICAL EQUIPMENT ELEMENTS

Qty	Equipment Element	Item* No.	Estimated Life (Yr)	Capital Cost (1978 $)	Approximate Annual O&M Costs ($)	Estimated Salvage Value ($)
3	positive disp. pump and motor	1015	10	30,300 (10,100)*	900	300
3	centrifugal pump and motor	1016	10	18,900 (6,300)*	900	180
1	temp. stor. tank	302	20	9,500	1,000	500
-	demulsifier	--	--	- 0 -	150	- 0 -
1	oil/water separator	1213	20	13,900	1,500	700
40	portable tanks	304	10	36,000 (900)†	6,500	1,500
40	drums and pallets	305	5	3,000 (75)†	960	- 0 -
1	forklift	401	10	24,000	2,400	1,200
1	vacuum tank	503	10	20,000	2,000	1,000
1	flatbed trailer	513	10	8,700	870	400
1	truck-tractor	514	10	59,000	6,000	4,000
	contingency (10%)	--	--	22,330	--	--

Life Cycle Cost = $630,525
Total Annual Cost = $ 23,180

*Appendix D.
†Unit costs

The approximate pumping rate of the selected system pumps for short-lift distances are about 665 ℓ/min (175 gal/min) for the positive displacement pump and 532 ℓ/min (140 gal/min) for the centrifugal pump. The oil/water separator has a total throughput rate of 1,900 ℓ/min (500 gal/min). Temporary field-erectable storage can be provided with a storage capacity of up to 4,058,700ℓ (1,068,080 gal). Any flow of process effluents to other systems can be accommodated directly by the system or reduced by surge storage. The limiting rate of transfer therefore occurs at the pump.

By providing three pumps of each type, the system can establish a maximum throughput of about 1,786 ℓ/min (470 gal/min). Given a large-scale recovery operation producing a total throughput spill mass of 380,000ℓ (100,000 gal), the system is able to process the volume in less than one full working day. For smaller spills, the extra pumps serve as back-up units for the on-line pumps. Easily transported, field-erectable storage tanks are also available in a range of sizes (about 50 sizes ranging from 7,820 to 4,058,700ℓ (2,058 to 1,068,080 gal).

Technical Feasibility of Development Including Critical Elements--
All equipment components included in System OS-1 are available on the commercial market. Development of the equipment into a mobile Coast Guard response system would require little engineering expense other than proper sizing and acquisition of the components.

Environmental Impacts of System Operations and Mitigation Measures--
Potential for environmental impacts in the treatment system are the following:

- Overfilling or leakage from temporary storage tanks
- Disturbance of vegetation and soil surfaces by equipment installation and vehicle operation
- Redischarge of oil caused by inefficient oil/water separation.

Overfilling of storage tanks during large-flow operations can be prevented by continuous monitoring of the fluid level in the tanks. Simple liquid level detection devices are available on the market. These sound a warning alarm when a predesignated tank volume (fill height) is reached. The impact of leakage from tanks may be minimized by erecting temporary berms around the perimeter of the tank and providing a supply of sorbent materials. Contingency plans should be prepared ahead of time for transferring the contents of a leaking storage tank to another holding facility. Directives for proper maintenance and operation of oily waste storage facilities are included in the Environmental Protection Agency's Regulations for Spill Prevention Control and Countermeasures (40 CFR, Part 112).

The redischarge of oil with aqueous oil/water separator effluents can be minimized by carefully monitoring the oil content in the stream. If the oil content is too high for discharge of the fluids back to the watercourse, as defined by controlling water quality standards, the fluids may have to be treated further (see System OS-2 below). Another available mitigating measure involves reducing the flow rate through the separator, thereby increasing the retention time and allowing for more effective partitioning of the oil and water phases in the unit.

Approximate Size and Weight of the Equipment--

Table 32 shows the approximate dimensions and weights of each equipment element for System OS-1. Plans for each element are shown in the indicated figures.

Transportability by Existing Coast Guard Vessels and Aircraft--

Appendix F describes the dimensions of various cargo holds for Coast Guard aircraft and vessels and the transportability of the equipment included in disposal system OS-1.

Transportability by Means Other Than Coast Guard Vessel and Aircraft -

See Appendix F.

Special Requirements--

The limiting element in System OS-1 is the 1,900 ℓ/min (500-gal/min) oil/water separator which cannot be transported to the field by sea or air. If the smaller separators are used, they can be transported but will double the processing time for a given volume of spill mass.

Specially trained Coast Guard personnel are required for installation and operation of all equipment elements. During simultaneous operation of all equipment elements, it is estimated that a maximum crew of six persons is required. This includes one pump tender, two persons for tank erection and monitoring, one person for monitoring the oil/water separator, a truck driver, and one forklift operator. Additional support vehicles may be required for transporting the crew to the field of operation.

Diesel fuel must also be provided for operation of the pump motors and forklift. These items have their own fuel tanks. For prolonged operation (more than 6 hr), a small tank truck may be required in order to maintain the fuel supply at the site.

TABLE 32. OS-1: DIMENSIONS AND WEIGHTS OF CRITICAL EQUIPMENT ELEMENTS

Equipment Element	Item No.	L (m)	W (m)	H (m)	Weight (kg)	Figure:*
Positive displacement pumps	1015	0.60	0.45	0.33	215	E-20
Centrifugal pumps	1016	1.5	0.45	0.6	184	E-21
Temporary storage tanks (in envelope)	302	1.2	3	1.2	2,700	E-2
Oil/water separator	1213	3.86	2.08	1.50	1,910	E-22
Portable storage tanks (Option A)	304	1.07	1.2	1.8	765	E-4
Drums on pallets (Option B) (in envelope)	305	1.9	1.5	2.4	6.80	E-5
Fork lift (Option B)	401	4.57	2.26	3.76	4,540	E-6
flatbed trailer	513	13.0	2.64	1.20	4,590	E-9
Vacuum tank	503	9.80	2.43	3.35	7,484	E-8
Truck-tractor	514	5.98	2.44	2.98	19,800	E-10

*For conceptual drawing, see figure number indicated, Appendix E.

System OS-2

The system is described as follows (Figure 26):

Liquids are received, pumped, stored, and demulsified or separated by an oil/water separator in the same manner as described in System OS-1. However, the aqueous discharges are further processed by one of the following on-site subsystems:

- Chemical treatment
- Biological treatment
- Filtration.

Since such processes produce some solids or sludges, sludge storage, dewatering, conveying, and disposal or transport off site are all system components which must be included. The aqueous effluents from these "polishing" treatment processes are monitored and discharged back to the watercourse.

Critical equipment elements of the system are shown in Table 33. The total life cycle cost and annual system cost, based on a system life of 20 yr, calculated for System OS-2, are $1,192,045 and $39,580, respectively.

Oils Which Can and Cannot be Handled--

The oil groups which can be handled by the initial pumping, demulsification, and oil/water separation phases of the system are the same as those for System OS-1.

The alternate treatment processes for the oil/water separator effluent or dilute effluents from other processing activities require a relatively low oil concentration in the influent stream. Any partitionable oils should be completely removed from the stream by the oil/water separator. The treatment units are best utilized for dissolved organic solids.

Reverse osmosis or ultrafiltration processes are best applied to solutions with a relatively low impurity concentration. Impurities in the waste solution should be stable, completely dissolved, emulsified, or chelated to avoid precipitation on the membrane. If one expects a waste solution to be handled continuously with such a system, a liter sample of waste solution should have no precipitation after standing for 12 hr.

Similar influent quality restrictions are given for the fluidized-bed technology recommended for in-field treatment of dilute aqueous wastes. To be effective, the organic content of the water must be readily biodegradable (e.g., present a relatively high measureable 5-day BOD). The process uses a biologcal slime growth to affect removals. Any oil which is considered even slightly toxic will not be treatable.

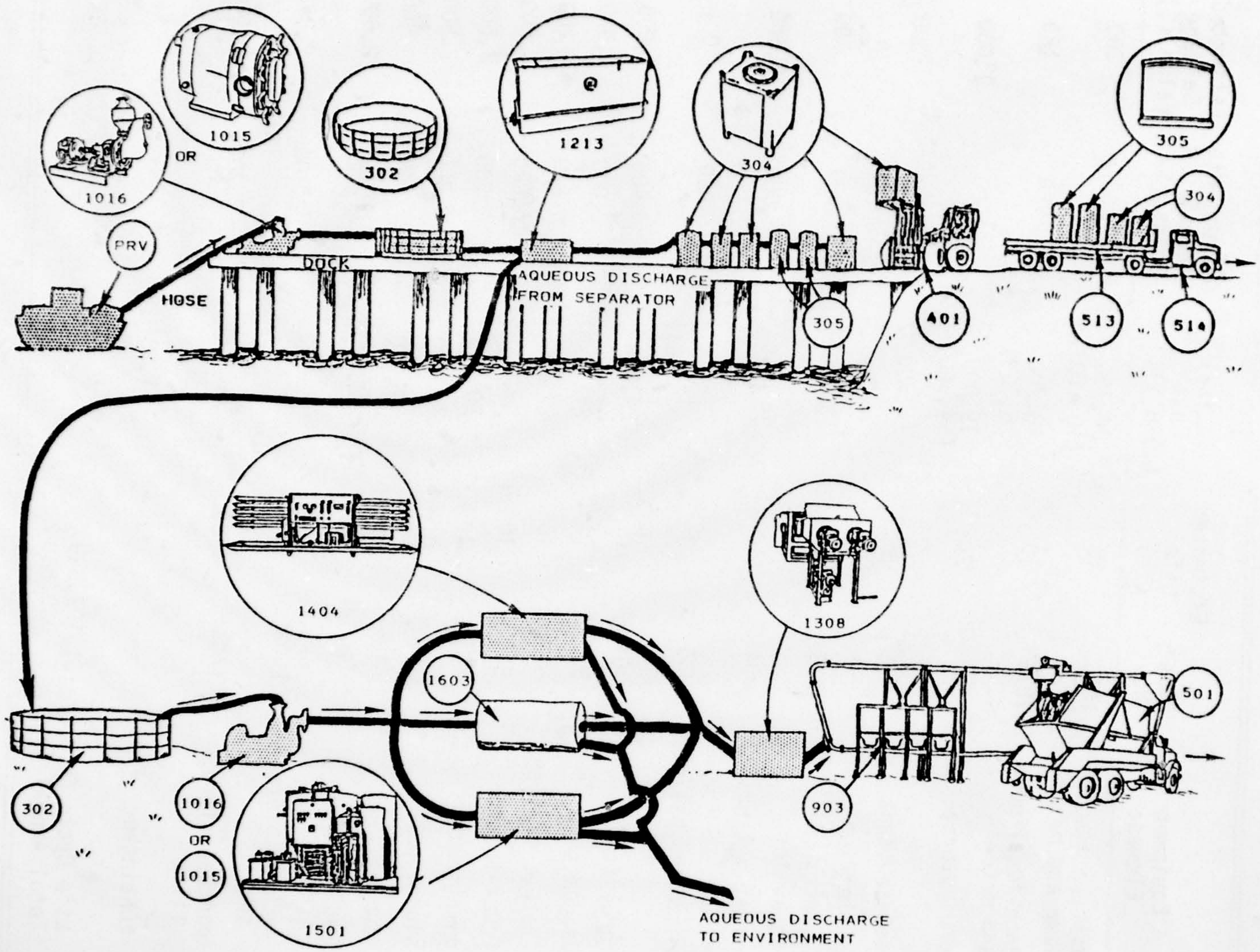

FIGURE 26. SYSTEM OS-2.

TABLE 33. SYSTEM OS-2: CRITICAL EQUIPMENT ELEMENTS

Qty	Equipment Element	Item* No.	Estimated Life (Yr)	Capital Cost (1978 $)	Approximate Annual O&M Costs ($)	Estimated Salvage Value ($)
3	positive disp. pump and motor	1015	10	30,300 (10,100)	900	300
3	centrifugal pump and motor	1016	10	18,900 (6,300)†	900	180
2	temp. storage tank	302	20	19,000 (9,500)†	2,000	1,000
1	open-top tank	302	20	6,300	800	300
-	demulsifier	--	--	- 0 -	150	- 0 -
1	oil/water separator	1213	20	13,900	1,500	700
40	portable tanks	304	10	36,000 (900)†	6,500	1,500
40	drums and pallets	305	5	3,000 (75)†	960	- 0 -
1	forklift	401	10	24,000	2,400	1,200
1	vacuum tank	503	10	20,000	2,000	1,000
1	flatbed trailer	513	10	8,700	870	400
1	truck-tractor	514	10	59,000	6,000	4,000
1	dump truck	501	10	50,000	3,700	2,500
1	sludge press	1308	10	50,000	4,000	2,500
1	conveyor	903	5	7,710	500	400
1	package chem. treat.	1501	20	52,000	2,000	2,600
1	package biolog. treat.	1603	20	55,000	2,100	2,800
1	package ultra-filt.	1404	20	60,000	2,300	3,000
	contingency (10%)	--	--	51,381	--	--
	Life Cycle Cost = $1,192,045					
	Total Annual Cost = $ 39,580					

*Appendix D.
†Unit costs

Chemical treatment of dilute oil/water separator effluents is an alternative to filtration or biological treatment. Precipitating agents for a number of organic compounds are available and can be selected to match the waste stream, and added in the package system.

Approximate Quantity of Spill Mass Which Can Be Handled--

The following maximum total throughput flow (influent) rates are estimated for each portable package unit:

Chemical	57 ℓ/min (15 gal/min)
Biological treatment	114 ℓ/min (30 gal/min)
Filtration	646 ℓ/min (170 gal/min)

Since the preceding System OS-1 pumps and oil/water separator can approach a throughput flow rate of 1,900 ℓ/min, 500 gal/min, it is probable that the three supplementary treatment options included in this system would be system limiting. An optional temporary storage tank is therefore included in this system to provide for storage of processed effluents and controlled feed to the selected package treatment system. Provision for a 570,000 ℓ (150,000 gal) tank would allow for continuous processing of 589,000 ℓ of spill mass before the system would have to discontinue receiving collected spill mass and process some portion of the stored volume.

Technical Feasibility of Development Including Critical Elements--

All equipment components included in System OS-2 are available on the commercial market. Development of the various treatment units (chemical, biological, or filtration) into a mobile system would require adaptation of the package units to mounting on skids or a flatbed truck. Auxilliary service and pumping equipment must also be adapted for mobile applications.

Environmental Impacts of System Operations and Mitigation Measures--

See description of System OS-1.

Approximate Size and Weight of the Equipment--

Table 34 shows the approximate dimensions and weights of each equipment element for System OS-2. Plans for each element are shown in the indicated figures.

Transportability by Existing Coast Guard Vessels and Aircraft--

Appendix F describes the dimensions of various cargo holds for Coast Guard aircraft and vessels and the transportability of equipment included in disposal System OS-2.

TABLE 34. SYSTEM OS-2: DIMENSIONS AND WEIGHTS OF CRITICAL EQUIPMENT ELEMENTS

Equipment Element	Item No.	L(m)	W (m)	H (m)	D	Weight (kg)	Figure*
Positive disp. pump & motor	1015	0.60	0.45	0.33	--	215	E-20
Centrifugal pump & motor	1016	1.5	0.45	0.60	--	184	E-21
Temporary tank (in envelope)	302	1.2	3.0	5.8	--	15260	E-2
Temporary tank (in envelope)	302	1.2	3.0	1.2	--	2700	E-2
Oil/water separator	1213	3.86	2.08	1.50	--	1910	E-22
Portable tanks	304	1.07	1.2	1.8	--	765	E-4
Drums & pallets	305	1.9	1.5	2.4	--	6.80	E-5
Fork lift	401	4.57	2.26	3.76	--	4540	E-6
Vacuum tank	503	9.80	2.43	3.35	--	7484	E-8
Flatbed trailer	513	13.0	2.64	1.20	--	4590	E-9
Truck-tractor	514	5.98	2.44	2.98	--	19800	E-10
Dump truck	501	5.1	2.43	1.80	--	2358	E-7
Sludge press	1308	4.00	2.40	1.12	--	2268	E-24
Conveyer	903	--	var.	--	--	var.	E-19
Package chem. treat.	1501	4.1	2.44	2.64	--	5670	E-26
Package bio. treat.	1603	--	--	4.7	0.46	~5000	E-27
Package ultra-filt.	1404	4.57	1.22	1.83	--	2313	

*For conceptual drawing, see figure number indicated, Appendix E.

Transportability by Means Other Than Coast Guard Vessel and Aircraft--
See Appendix F.

Special Requirements--
Specially trained Coast Guard personnel are required for installation and operation of all equipment elements. During simultaneous operation of all equipment elements, it is estimated that a maximum crew of six persons is required. This includes one pump tender, two persons for tank erection and monitoring, a treatment plant operator, and two drivers.

System OS-3

The system is described as follows (Figure 27):

> Liquids are received, pumped, stored, and demulsified or separated by an oil/water separator in the same manner as described in System OS-1. Concentrated recovered liquids are burned in a portable, on-site incinerator system.

Critical equipment elements of the system are shown in Table 35. The total life cycle cost and annual system cost, based on a system lifetime of 20 yr are $1,226,871 and $30,080 respectively.

Oils Which Can and Cannot be Handled--
Any combustible oil which is relatively free of water can be burned in the portable incinerator. For a combustion flame to be self-sustaining, the air/combustible mixture must have a minimum energy level of about 50 Btu/scf. If the oil to be disposed does not have sufficient Btu content, then an independent source of fuel (natural gas, l.p. gas, or oil) is injected to the combustion chamber to bring the charge to ignition temperature and the sustained combustion at an efficient level. The incinerator included in this system is adaptable to either method of operation and is therefore applicable to all groups of oils as described in Appendix A. The limiting factor in the handling of oil spill masses is, therefore, the oil/water separator component as described under system OS-1 (good for Groups I, II, IV, and marginal for the more viscous oils in Groups III and V). Group IV should also be avoided due to explosion danger.

The incinerator included in this system is also capable of burning organic sludges such as those which can be generated by Systems OS-2.

Approximate Quantity of Spill Mass Which Can Be Handled--
The incinerator burning capacity for liquid wastes is about 7.6 ℓ/min (2 gal/min). Assuming processing of a 50 percent oil/50 percent water mixture at 1,900 ℓ/min (500 gal/min) in the oil/water separator, a maximum possible concentrated oil discharge rate of 950 ℓ/min (250 gal/min) (actually somewhat high,

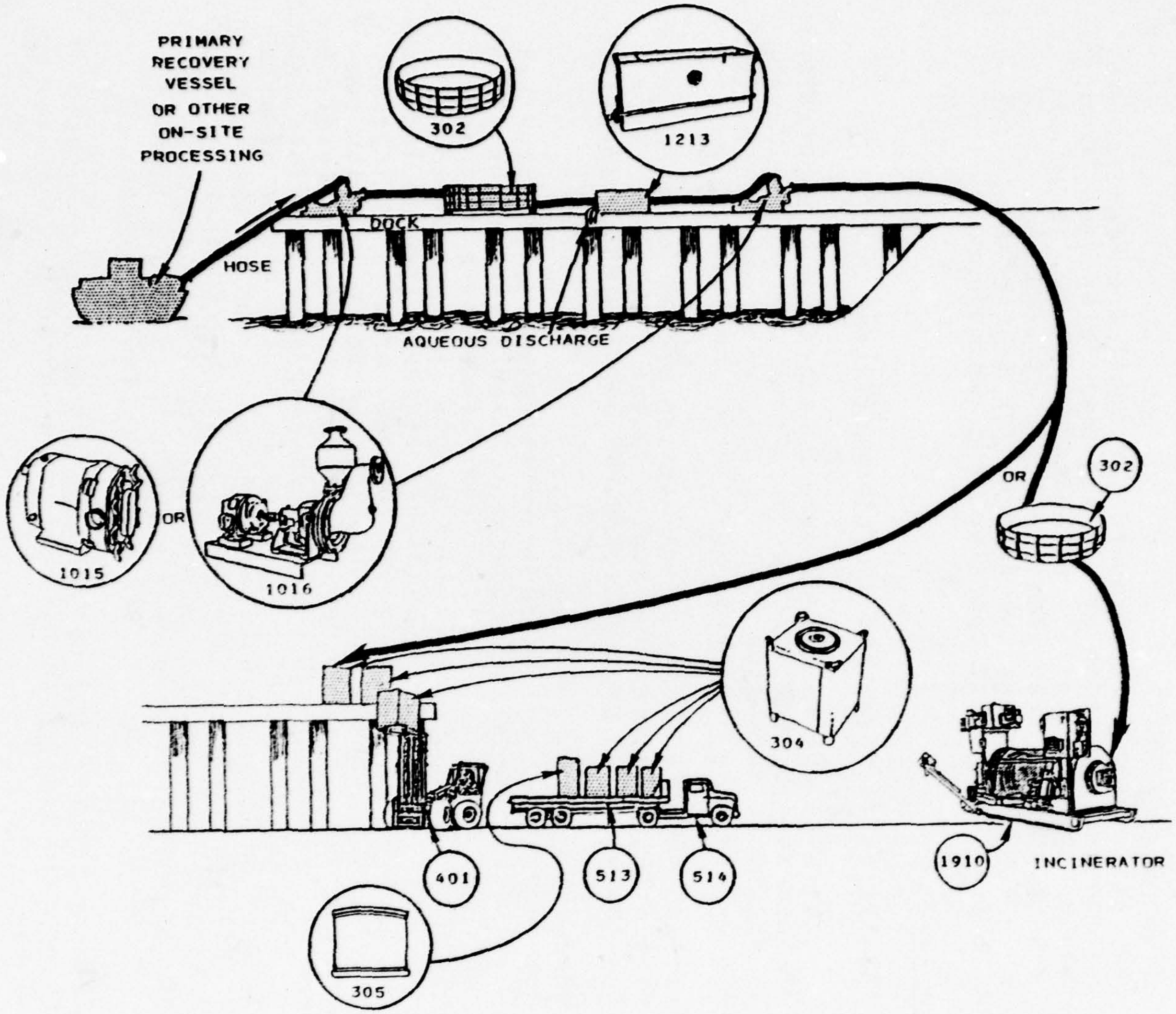

FIGURE 27. SYSTEM OS-3.

TABLE 35. SYSTEM OS-3: CRITICAL EQUIPMENT ELEMENTS

Qty	Equipment Element	Item* No.	Estimated Life (Yr)	Capital Cost (1978 $)	Approximate Annual O&M Costs ($)	Estimated Salvage Value ($)
3	positive disp. pump and motor	1015	10	30,300 (10,100)†	900	300
4	centrifugal pump and motor	1016	10	25,200 (6,300)†	1,200	240
1	temp. storage tank	302	20	9,500	1,000	500
1	temp. storage tank	302	20	3,200	600	200
-	demulsifier	--	--	- 0 -	150	- 0 -
1	oil/water separator	1213	20	13,900	1,500	700
40	portable tanks	304	10	36,000 (900)†	6,500	1,500
40	drums and pallets	305	5	3,000 (75)†	960	- 0 -
1	forklift	401	10	24,000	2,400	1,200
1	vacuum tank	503	10	20,000	2,000	1,000
2	flatbed trailer	513	10	17,400 (8,700)†	870	400
1	truck-tractor	514	10	118,000 (59,000)†	6,000	4,000
1	incinerator	1910	10	190,000	6,000	10,000
	contingency (10%)	--	--	30,760	--	--

Life Cycle Cost = $1,226,871
Total Annual Cost = $ 30,080

*Appendix D.
†Unit costs

based on 100 percent separation efficiency) would be achieved. Temporary storage, similar to that required for System OS-2, is therefore required to accommodate the oil/water separator discharge until it can be burned in the slower incinerator unit. By providing a 42,750 ℓ (11,250 gal) tank, about 86,184 ℓ (22,680 gal) of spill mass could be processed before the system would have to discontinue receiving collected spill mass and process some portion of the stored volume. Complete incineration of 42,750 ℓ (11,550 gal) of oil would take approximately 4 days.

Incineration rate is the limiting factor in this system, and it is not recommended for large spill mass volumes (in excess of 76,000 ℓ (20,000 gal).

Technical Feasibility of Development Including Critical Elements--

All equipment components included in System OS-3 are available on the commercial market. Development of the incinerator unit into a portable, possibly mobile system would require adaptation of the unit and supporting utilities to mounting on a flatbed truck or on skids.

Environmental Impacts of System Operations and Mitigation Measures--

See discussion of disposal System OS-1. Additional environmental impact will occur from stack emissions from the incinerator unit. Use of this system is therefore not recommended at shorelines in heavily populated or urbanized zones. In remote areas, the impact from any incinerator emissions is secondary to the need for effective disposal of the spilled oil.

Approximate Size and Weight of the Equipment--

Table 36 shows the approximate dimensions and weights of each equipment element for System OS-3. Plans for each element are shown in the indicated figures.

Transportability by Existing Coast Guard Vessel and Aircraft--

Appendix F describes the dimensions of various cargo holds for Coast Guard aircraft and vessels and the transportability of equipment included in System OS-3.

Transportability by Means Other Than Coast Guard Vessel and Aircraft--

See Appendix F.

Special Requirements--

Specially trained Coast Guard personnel are required for installation and operation of all equipment elements. During operation of all equipment elements, it is estimated that a maximum crew of eight persons are required. This includes two pump tenders, one person for tank erection and one driver. Additional crew will be required for operation of the system as described under System OS-1.

TABLE 36. SYSTEM OS-3: DIMENSIONS AND WEIGHTS OF CRITICAL EQUIPMENT ELEMENTS

Equipment Element	Item No.	L (m)	W (m)	H (m)	Weight (kg)	Figure*
Positive disp. pump & motor	1015	0.60	0.45	0.33	215	E-20
Centrifugal pump & motor	1016	1.5	0.45	0.60	184	E-21
Temporary tank (in envelope)	302	1.2	3.0	5.8	15260	E-2
Temporary tank (in envelope)	302	1.2	3.0	1.2	2700	E-2
Oil/water separator	1213	3.86	2.08	1.50	1910	E-22
Portable tanks	304	1.07	1.2	1.8	765	E-4
Drums & pallets	305	1.9	1.5	2.4	6.80	E-5
Fork lift	401	4.57	2.26	3.76	4540	E-6
Vacuum tank	503	9.80	2.43	3.35	7484	E-8
Flatbed trailer	513	13.0	2.64	1.20	4590	E-9
Truck-tractor	514	5.98	2.44	2.98	19800	E-10
Incinerator	1910	5.96	2.11	9.91	19720	E-31

*For conceptual drawing, see figure indicated, Appendix E.

Additional fuel may be required for the incinerator system and may be supplied by an additional small tank truck.

System OS-4

The system is described as follows (Figure 28):

> Liquids are pumped from the primary recovery vessel (PRV), or from other on-site processing activities, into a temporary storage tank. Aqueous and/or concentrated wastes are disposed by on-site burial or land cultivation, using a tank truck or cultivator and earth moving equipment. The disposal site is analyzed and monitored for potential soil and groundwater contamination.

Critical equipment elements of the system are shown in Table 37. The total life cycle cost and annual system cost, based on a system life of 20 yr, are estimated to be $240,678 and $7,000, respectively.

Oils Which Can and Cannot Be Handled--

All oil groups defined in Appendix A may be disposed to land if they are present in aqueous wastes in small quantities. Concentrated waste oils in Groups II and III may also be applied to land disposal. Concentrated oils in Groups I, IV, and V may generate explosive vapors and should not be applied to land using heavy machinery. The lighter viscosity and mildly toxic characteristics of the water-soluble fractions of the jet fuels and kerosene make them more able to pass through a soil/ground water matrix and damage adjacent water courses. Other processing options should be considered for these groups and, if no other option exists, land disposal should be conducted only under carefully controlled and monitored conditions.

Approximate Quantity of Spill Mass Which Can Be Handled--

The volume of liquids which are disposed of by System OS-4 may be determined by the pump delivery capability, the storage tank capacity, the rate and method of application to the land, or the disposal site capacity.

Capacity of the land disposal site is determined on a case-by-case basis. A disposal equipment system should, therefore, be provided which is capable of delivering and applying waste fluids as rapidly as possible.

The approximate pumping rate of the selected pumps for short vertical lift distances is 665 ℓ/min (175 gal/min) for the positive displacement pump and 532 ℓ/min (140 gal/min) for the centrifugal pump. (Actual delivery rates are dependent upon fluid viscosities and other factors.) The field-erectable temporary storage tank can provide up to 42,773 ℓ (11,256 gal) storage

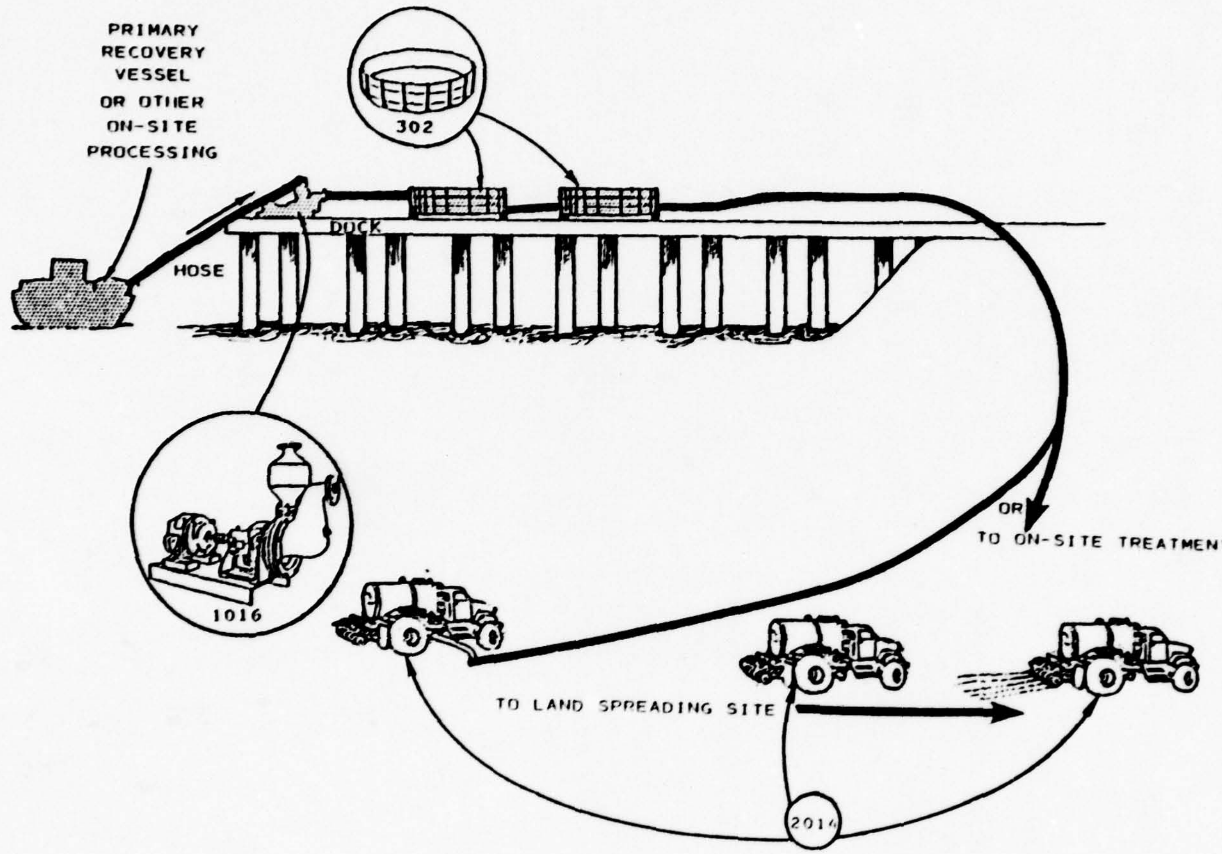

FIGURE 28. SYSTEM OS-4.

TABLE 37. SYSTEM OS-4: CRITICAL EQUIPMENT ELEMENTS

Qty	Equipment Element	Item No.*	Estimated Life (Yr)	Capital Cost (1978 $)	Approximate Annual O&M Costs ($)	Estimated Salvage Value ($)
2	positive disp. pump and motor	1015	10	20,200 (10,100)†	600	200
2	centrifugal pump and motor	1016	10	12,600 (6,300)†	600	120
2	temp. storage tank	302	20	6,400 (3,200)†	800	300
1	liquid applicator vacuum truck	2014	10	53,000	5,000	2,600
	contingency (10%)	--	--	9,220	--	--

Life Cycle Cost = $240,678
Total Annual Cost = $ 7,000

*Appendix D.

†Unit costs.

capacity. The tank truck equipped with the subsurface applicator can inject about 2,660 ℓ (700 gal) of waste material per minute. The liquid applicators are equipped with 6,080 ℓ (1,600 gal) capacity tanks. Approximately six loads can be run per hour allowing for a 5 to 6 min load-unload cycle and 4 to 5 min for on-the-road time traveling between the storage tank and the disposal site. Therefore, during an 8-hr day, up to 291,840 ℓ (76,800 gal) of waste may be applied. Therefore,during a 1-hr period, the pump can deliver a maximum of 39,900 ℓ (10,500 gal) to the holding tank, and the truck can remove 36,480 ℓ (9,600 gal). This leaves a surplus in the tank of 3,420 ℓ/hr (900 gal/hr). For processing 570,000 ℓ (150,000 gal) of spill mass fluids, this surplus would become 49,020 ℓ (12,900 gal) during a 14.3-hr operational period. Additional storage capacity of 34,200 ℓ (9,000 gal) should also be provided for dealing with truck delays on the road or at the disposal site. Therefore, the two portable storage tanks with a storage capacity of 42,773 ℓ (11,256 gal) each are included in the system.

Technical Feasibility of Development Including Critical Elements--

All equipment components included in System OS-4 are available on the commercial market and are readily transferred to the site of operations. Development of the equipment into a mobile Coast Guard response system would require little engineering expense other than proper sizing and acquisition of the components.

Environmental Impacts of System Operations and Mitigation Measures--

Potential for environmental impacts from operation of on-site disposal System OS-4 include the following:

- Accidental spillage during pump-out of the primary recovery vessel or transfer of liquid wastes from other on-site operations

- Overfilling or leakage from the temporary storage tanks

- Contamination of groundwater and/or adjacent surface waters and soils caused by improper disposal site selection and/or waste application.

Accidental oily discharges from water-to-shore transfers can be contained by providing a boom around the unloading vessel and all transfer operations. Sorbent materials should also be provided to retrieve any small volumes of discharged wastes.

Overfilling of the temporary storage tanks can be prevented by the same mitigating procedures described for System OS-1.

Manuals for proper oily waste disposal site selection and operation are available (56) and should be utilized during the

application of System OS-4. The following is a summary of some basic site location procedures which should be followed:

- Identify existing waste disposal sites
- Identify vacant land
  - Use maps, aerial or ground reconnaissance
  - Confer with large landowners/brokers
- Determine ownership
  - For assessment of difficulties to secure
  - For personal contract negotiations
  - To determine whether public lands are preferred
- Gather background information
- Develop environmental protection criteria
- Evaluate suitability of each prospective site
- Select site best suited for debris disposal.

If a controlled waste disposal site operated by a municipality or industry is located nearby, it should be considered as a good alternative to on-site disposal. A discussion of land disposal of oily wastes at established sites is included in Appendix G of this report.

Potential environmental problems to expect at an oil spill disposal site include the following:

- Surface runoff of oily materials
- Surface settlement and ponding of surface waters
- Contamination of groundwater with constituents of the disposed mass by
  - Infiltration of groundwater into the debris
  - Leaching of oils from the disposed mass to the groundwater
- Retarded oil degradation (at land cultivation sites).

A monitoring program should be developed to help control the impact of the above phenomena.

Approximate Size and Weight of the Equipment--

Table 38 shows the approximate dimensions and weights of each equipment element for System OS-4. Plans for each element are shown in the indicated figures.

TABLE 38. SYSTEM OS-4: DIMENSIONS AND WEIGHTS OF CRITICAL EQUIPMENT ELEMENTS

Equipment Element	Item No.	L (m)	W (m)	H (m)	Weight (kg)	Figure*
Positive displacement pumps and motor	1015	0.60	0.45	0.33	215	E-20
Centrifugal pumps and motor	1016	1.5	0.45	0.60	184	E-21
Open-top tanks (in envelope)	302	1.2	3.0	0.3	885	E-2
Liquid applicator vacuum truck	2014	5.[illegible]	2.9	3.4	3,000	E-33

*For conceptual drawing, see figure number indicated, Appendix E.

Transportability by Existing Coast Guard Vessels and Aircraft--

Appendix F describes the dimensions of various cargo holds for Coast Guard aircraft and vessels and the transportability of equipment included in system OS-4.

Transportability by Means Other Than Coast Guard Vessel and Aircraft--

See Appendix F.

Special Requirements--

Specially trained Coast Guard personnel are required for installation and operation of all equipment elements. During simultaneous operation of the oily waste receiving and disposal processes, a maximum crew of five persons is required. This includes one pump tender, two persons for tank erection and monitoring, one land disposal site caretaker, and one heavy equipment operator.

Diesel fuel must be provided for operation of the pump motors and vacuum truck. These items have their own fuel tanks. On-site treatment of fluids by land application may include preparation of a lagooning facility. The estimated costs for lagoon site preparation and closure of three different size operations are presented in Appendix G.

SUMMARY OF SECTION III

A variety of commercially available equipment is directly applicable to the handling and disposal of recovered oil spill masses. Most equipment may also be used for dealing with floating chemical spill materials, although modification of storage vessels and transfer equipment is necessary to protect crew personnel and the public when volatile and/or toxic chemicals are present.

Thirteen disposal equipment systems (plus four auxiliary systems) are identified based on literature and interview descriptions of past disposal experiences. For spill masses includiding oils, some systems are applicable both in warm and cold weather, while others are useful only in warmer conditions.

Four auxiliary equipment systems for on-site treatment and disposal of recovered liquids and solids are also identified. These equipment systems may be used in conjunction with others to provide additional "polishing" treatment when required by regulatory agencies, or when transport of spill materials to contracted off-site disposal facilities is not feasible.

IV. SPILL DISPOSAL EQUIPMENT SYSTEMS FOR OILS AND FLOATING CHEMICALS

SCENARIO C - OIL OR FLOATING CHEMICAL, NO DEBRIS, CALM WEATHER, WARM AIR TEMPERATURE

Scenario C is defined as follows:

> Oil or floating chemical dispersed in water, no solid debris, calm weather, warm air temperature.

Oils and floating chemicals to be included and considered under Scenario C include the six groups as defined in Appendix B. Environmental conditions include a moderate air temperature of from 15 to 25°C. Typical chemical/water emulsions encountered can include up to 50 percent water, although this can vary over a wide range depending upon environmental conditions at the spill site and method of recovery.

<u>Chemical Group-Insoluble Volatile Floater (IVF)-I</u>

This chemical group includes two oils: JP-4 and coal tar. Disposal equipment systems for oil Groups IV (JP-4) and V (coal tar) are presented under Section III of this report. These include equipment Systems 2, 3, and 4.

There are 33 floating chemicals in this group which include many of the short-chain alkane and alkene isomers, as well as gasolines and other light volatile distillates. There are no toxic floaters in IVF-I.

A review of all chemicals included in IVF-I indicates that all are applicable to the systems defined in Section III for oils: Systems 2, 3, and 4.

<u>Chemical Group IVF-II</u>

None of the oils listed in Appendix A are included in this group. These insoluble volatile floating chemicals have a density in the neighborhood of 53 lb/ft^3 at 20°C and a flash point below 100°C. The group also includes four low-temperature solid floaters (LTSF) and three toxic floaters (TF): turpentine, o-xylene, and p-xylene.

Group			Recommended Disposal Equipment System(s)
Group II	oil: crude oil: diesel oil: fuel: No. 2 oil: fuel: No. 2-D oil: absorption oil: lubricating oil: mineral	oil: mineral seal oil: rosin oil: sperm oil: tall oil: spindle	1, 2, 3, 4
Group III	asphalt oil: fuel: No. 4 oil: fuel: No. 5 oil: fuel: No. 6 oil: motor oil: neatsfoot	oil: resin oil: road oil: spray oil: tanner's oil: transformer oil: penetrating	1, 2, 3

Chemical Group INF-I

This group includes eight relatively non-toxic and two toxic insoluble non-volatile floating chemicals with densities around 49 or 50 lb/ft^3 at 20° C. Included in this group are some linear alcohols, many olefins, and several aromatics (diethylbenzene and Dowtherm). The two toxic floaters (TF), benzaldehyde and 2-ethyl-3-propylacrolein, are both aldehydes.

Some of the linear alcohols may be handled and disposed by previously described System 1. The other chemicals, the olefins and aromatics, should not be incinerated on site. Handling and disposal by Systems 2, 3, or 4 are recommended.

The two toxic floaters, benzaldehyde and 2-ethyl-3-propylacrolein, can be collected from the site of operations and transferred to an off-site disposal or reprocessing facility by the equipment included in Systems 2 or 3. Storage tanks should be pressure sealable to prevent the escape of toxic vapors. All disposal crew personnel involved with receiving the collected spill mass can be provided with protective clothing and enclosed breathing apparatus.

Chemical Group INF-II

Twenty-one insoluble, nonvolatile floating chemicals, including one toxic floater (naphtha-coal tar) are included in this group. These materials exhibit a density close to 53 to 55 lb/ft^3 at 20°C, and include naphthas, esters, and the heavier, long-chain alcohols. Disposal equipment Systems 1, 2, 3, and 4 are directly applicable to dealing with all the chemicals included in INF-II.

Systems 2 and 3 should be used with storage vessels modified to contain all potential toxic vapors. Personnel involved

with transfer points in Systems 2 or 3 should be provided with protective clothing.

Chemical Group INF-III

Asphalt blends and edible oils comprise the majority of 11 floating chemicals included in this group,and have relatively high viscosities (about 1,700 centipoise at 20°C). Most of these oils can be incinerated or transported to shore for on-site treatment or delivery to an off-site processing disposal facility. Disposal equipment Systems 1, 2, 3, and 4 are equally applicable to this group of chemicals. Positive displacement pumps should be selected over centrifugal pumps for conducting collection and transfer operations.

No toxic floating chemicals are included in group INF-III.

Chemical Groups-Soluble Volatile Floater (SVF) and Soluble Non-Volatile Floaters (SNF)

The soluble volatile and nonvolatile floaters may be collected in the same manner as the insoluble chemicals. The primary difference is that incident water collected with the spill mass will be contaminated and contain a dissolved portion of the chemical. Separated spill mass water fractions must therefore be further processed by one of the four on-site treatment systems (OS-1, OS-2, OS-3, or OS-4) before being discharged to the receiving environment.

The soluble nature of many of the chemicals in these two overall groups means that many are toxic floaters.

The soluble volatile floaters (SVF-I, SVF-II, and SVF-III) include the lighter and heavier esters (acetates) as relatively nontoxic compounds, and the monomers and polymerizable esters (acrylates) as toxic constituents.

The soluble nonvolatile floaters (SNF-I, SNF-II, and SNF-III) include alcohols, nontoxic acrylates, and other miscellaneous compounds. No toxic floaters are included in the soluble nonvolatile floater (SNF) grouping.

All nontoxic chemicals in the SVF and SNF groups can generally be handled by Systems 1, 2, 3, or 4 (Section III). Systems 2 and 3,with storage modifications and protective clothing,should be used for dealing with the toxic floaters (acrylates, toluene derivatives, hydroperoxide, and amines) encountered in the soluble volatile floaters.

SCENARIO D - OIL OR CHEMICAL GROUP-LOW TEMPERATURE "SOLID" FLOATER (LTSF), NO DEBRIS, STORMY WEATHER, COLD AIR TEMPERATURE

Scenario D is defined as follows:

Oil or floating chemical dispersed in the water, no solid debris, stormy weather, cold air temperature.

Certain chemicals, exclusive of oils listed in Appendix A, are identified as low-temperature "solid" floaters (LTSF). Constituents of this group exhibit one of the following characteristics:

- Chemicals which become highly viscous at or near $0^{o}C$
- Polymeric chemicals which become brittle at or near $0^{o}C$
- Chemicals with freezing points at or near $0^{o}C$.

All materials in this group present a need for special transfer equipment in scenarios exhibiting cold air temperatures.

The following chemicals act as LTSFs:

IVF-II: benzene (t), tetradecanol, toluene 2, 4-diisocyanate (t), p-xylene (t)

IVF-III: wax-carnauba, wax-paraffin

INF-I: dicyclopentadiene, Dowtherm

INF-II: 2-ethyl hexanol, isodecyl alcohol, some linear alcohols, nonanol

INF-III: asphalt blending-straight run; oils, edible - cottonseed

SNF-I: isooctyl alcohol

SNF-II: phenol (t)

SNF-III: adiponitrile (t), aniline (t)

Some of the chemicals determined to be low temperature "solid" floaters are listed as toxic floaters (TF), and are so indicated by a (t) in the above list.

It is determined that only those chemicals included as non-toxic LTSF can be accommodated by the modified disposal System 1 described in Section III of this report under Scenario B for oils. Toxic chemicals must be handled by systems described in Section V.

SCENARIO I - OIL OR FLOATING CHEMICAL (SLUDGE OR SEDIMENT, INORGANIC SORBENTS MIX), CALM WEATHER, WARM AIR TEMPERATURE

Scenario I is defined as follows:

Oil or floating chemicals mainly consisting of heavy sludge, or mixed with soil, sand, sediments, inorganic sorbents, etc.; calm weather, warm air temperature.

Soils and floating chemicals included in this scenario are divided into six groups (Appendix B). Environmental conditions include moderate air temperature of from 15 to 25°C. Typical solid/chemical mixture ratios up to 5 to 1 are anticipated. Solids mixed with spill masses collected from off-shore operations will probably consist of dredged sediment or sand slurries, or oil-sorbent mixtures. Debris recovered at on-shore sites will not exhibit fluid characteristics and will probably consist of chemical-contaminated sand or soils. It is anticipated that the sludges and slurry materials will be pumpable by centrifugal pumps or by progressive cavity systems.

Handling and disposal of the following chemical groups are considered in conjunction with the debris types defined for this Scenario I.

Chemical Group IVF-I

This chemical group includes two oils: JP-4 and coal tar. Disposal equipment systems for oil Group IV (JP-4) and V (coal tar) are presented in Section III. These include equipment Systems 5, 6, and 7.

There are 33 floating chemicals in this group which include many of the short-chain alkane and alkene isomers, as well as gasolines and other light volatile distillates. These materials commonly become associated with soils, sands, and sorbent materials during spills and subsequent clean-up operations. There are no toxic floaters in IVF-I. Review of all chemical debris mixtures included in Group IVF-I under Scenario I, indicates that all can be handled by the systems previously defined for such oil-debris mixtures: Systems 5, 6, and 7.

Chemical Group IVF-II

Under the environmental conditions defined for Scenario I, all of the relatively nontoxic chemicals in this group can be handled by equipment Systems 5, 6, and 7. None of the oils listed in Appendix A are included in this group. The group includes three toxic floaters (TF): turpentine, o-xylene, and p-xylene.

The toxic floaters included in this group should be handled using System 5 for off-shore recovery, and System 7 for on-shore recovery. Equipment modifications include requirements for sealed, nonvented tanks on vacuum trucks, and for on-site storage. Such vessels will prevent toxic fumes from coming in contact with the disposal crew. The systems also must include provisions for protective clothing and closed breathing apparatus for the crew members stationed at collection and transfer operations.

Chemical Group IVF-III

Tridecanol, carnauba wax, and paraffin are the three floating chemicals comprising this group. There are no toxic floaters. The chemicals are highly viscous, yet may still become mixed with fine debris materials. Conveyor and other transfer storage systems designed to handle sludges, soils, etc., will generally accommodate these heavy compounds. Disposal Systems 5, 6, and 7 are all able to accommodate these chemical-debris spill-mass mixtures.

Chemical Group IVF-IV

This group is comprised of oil Group IV: jet fuel-JP-4. Systems 5, 6, and 7 are recommended for handling oil-debris mixtures.

Chemical Group IVF-V

This group is comprised of oil Group V: coal tar. Systems 5, 6, and 7 are recommended for oil Group V.

Chemical Group INF-Oils

All oils in this group are also included in the oil groups considered in Section III of this report. The oil-debris mixtures can be disposed of by any of the Systems 5, 6, or 7.

Other Chemical Groups

The remaining floating chemical groups and debris mixtures considered under Scenario I may all be accommodated by Systems 5, 6, or 7.

Compounds which are included in the toxic floaters (TF) group must be accommodated by System 5 or 7, modified to provide waste vapor containment and protective clothing and breathing apparatus for the disposal crew.

SCENARIO J - OIL OR FLOATING CHEMICAL (SLUDGE OR SEDIMENT, INORGANIC SORBENTS MIX), STORMY WEATHER, COLD AIR TEMPERATURE - CHEMICAL GROUP LTSF

Scenario J is defined as follows:

Oil or floating chemicals mainly consisting of heavy sludge, or mixed with soil, sand, sediments, inorganic sorbents, etc.; stormy weather, cold air temperature

All chemicals warranting special consideration under this scenario's defined environmental conditions (air temperature at or below 0°C) are included in the group called "Low Temperature Solid Floaters" (LTSF). All these materials are listed as follows:

dowtherm	2-ethyl hexanol
benzene (t)	isodecyl alcohol
tetradecanol	asphalt blending-straight run
toluene 2, 4-diisocyanate (t)	oils, edible-cottonseed
p-xylene (t)	isooctyl alcohol
wax-carnauba	phenol (t)
wax-paraffin	adiponitrile (t)
dicyclopentadiene	aniline (t)
	aldrin (t)

Some of the chemicals listed above are toxic floaters and are so indicated by a (t). It is therefore determined that only those chemicals included as nontoxic LTSF, and involved in spill masses defined by Scenario J, can be accommodated by System 6. Toxic chemicals must be handled by systems proposed in Section V for hazardous chemicals.

SCENARIO O - OIL OR FLOATING CHEMICAL/ORGANIC SOLIDS MIX, CALM WEATHER, WARM AIR TEMPERATURE

Scenario O is defined as follows:

Oil or floating chemical mixed with large amounts of organic solids (seaweed, storm debris, driftwood, flotsam, organic sorbents, etc.); calm weather, warm air temperature.

Oils and floating chemicals included in this scenario are divided into six groups based on density, volatility, solubility, and viscosity (Appendix B). Environmental conditions include moderate air temperature of 15 to 25°C. Typically, the total spill mass volume can be as much as 100 times the volume of the original spilled component. The oil and chemicals may be adhering to the organic debris or absorbed within tissues, void spaces, etc., or both. The recovered spill mass is not pumpable, and must be collected and transferred without the assistance of pumping.

Handling and disposal of the following chemical groups are considered in conjunction with the debris types and environmental conditions defined for Scenario O.

Chemical Group IVF-I

This group includes two oils: JP-4 and coal tar. Disposal equipment systems for oil Groups IV (JP-4) and V (coal tar) are presented under Scenario M in the previous section. Disposal equipment systems applied to these oil groups are Systems 8, 9, and 11.

The 33 floating chemicals in Group IVF-I include many of the short-chain alkane and alkene isomers, as well as gasolines and other light volatile distillates. These materials commonly become associated with large organic debris materials during spills and subsequent clean-up operations. There are no toxic floaters included in group IVF-I.

Review of all chemical-debris mixtures possible under Group IVF-I and Scenario O, indicates that all of them can be handled by the systems defined for such oil-debris mixtures: Systems 8, 9, and 11. System 10 includes a shredding or chipping process, and is avoided due to possible generation of explosive conditions in the grinding or chipping chamber.

Chemical Group IVF-II

None of the oils listed in Appendix A are included in this group, which includes three toxic floaters (TF): turpentine, o-xylene, and p-xylene.

Since group IVF-II is defined as a volatile collection of compounds, shredding or chipping of organic debris without washing to remove adhering chemicals is not recommended. Systems 8, 9, and 11 are proposed for transporting and disposing of these spill-mass materials.

The toxic floaters included in this group should be transported directly to off-site treatment and/or disposal as stipulated under System 8, rather than processed on site as called for in Systems 9, 10, or 11. On-board handling of debris should also be minimized, and debris containers should be provided with sealable lids to contain dangerous vapors. The system equipment should include protective clothing and closed breathing apparatus for those working close to collection and debris transfer operations.

Chemical Group IVF-III

Tridecanol, carnauba wax, and paraffin are the three floating chemicals comprising this group, which does not include any

toxic floaters. The chemicals are highly viscous, yet may still become mixed with large organic materials. This, however, does not appreciably limit the mode of transfer and storage, which is already limited by the heterogeneous and bulky nature of the solid debris component. Therefore, disposal Systems 8, 9, and 11 are able to accommodate these chemical-debris spill-mass mixtures. System 10 is omitted because these compounds are considered volatile and could yield explosive vapors and associated fire hazards in chipping or shredding operations.

Chemical Group IVF-IV

This group is comprised of the oil Group IV (jet fuel JP-4). Systems 8, 9, and 11 are recommended for handling oil spill masses involving the volatile fuel.

Chemical Group IVF-V

This group is comprised of oil Group V: coal tar. Systems 8, 9, and 11 are recommended for handling oil spill masses involving the volatile organic mixture.

Chemical Group INF-Oils

All oils in this group are also included in the oil groups considered in Section III of this report. The oil-debris mixtures may be disposed by any of Systems 8, 9, 10, or 11, except the following oils:

JP-1	Oil: Fuel: No. 1
JP-3	Oil: Fuel: No. 1-D
JP-5	Oil: Range
	Kerosene

These oils must not be handled by System 10 because of their highly volatile characteristics.

Other Chemical Groups

The remaining floating chemicals and debris mixtures considered under Scenario 0 may all be accommodated by Systems 8, 9, 10, or 11.

Compounds which are included in the toxic floaters group (TF) must be handled by System 8 modified to provide waste vapor containment and protective clothing and breathing apparatus for the disposal crew. System 8 should be employed to transfer toxic chemicals directly to off-site processing.

SCENARIO P - OIL OR LTSF CHEMICAL/ORGANIC SOLIDS MIX, STORMY WEATHER, COLD AIR TEMPERATURE

Scenario P is defined as follows:

Oil or floating chemical mixed with large amounts of organic solids (seaweed, storm debris, driftwood, flotsam, organic sorbents, etc.); stormy weather, cold air temperature.

All chemicals warranting special consideration under this scenario's defined environmental conditions (air temperature at or below 0°C) are included in the group called "Low Temperature Solid Floaters" (LTSF). All these materials are listed as follows:

	wax-carnauba	asphalt blending-straight run
benzene (t)	wax-paraffin	
aldrin (t)		
tetradecanol	dicyclopentadiene	oils, edible: cotton seed
toluene 2, 4-diisocyanate (t)	Dowtherm	isooctyl alcohol
p-xylene (t)	2-ethyl hexanol	phenol (t)
aniline (t)	isodecyl alcohol	adiponitrile (t)

Some of the chemicals listed above are toxic floaters and are so indicated by a (t). It is therefore determined that only those chemicals included as nontoxic LTSF, and involved in spill masses defined by Scenario P, can be accommodated by the disposal System 8 described under Scenario M for oils. Toxic chemicals must be handled as described in Section V.

SCENARIO U - OIL OR FLOATING CHEMICAL/LARGE SOLIDS MIX, CALM WEATHER, WARM AIR TEMPERATURE

Scenario U is defined as follows:

Oil or floating chemicals, primarily soaking large solids (pieces of dock, vessels, trees, etc.); calm weather, warm air temperature.

Oils and floating chemicals included in this scenario are divided into six groups based on density, volatility, solubility and viscosity, and other factors (Appendix B). Environmental conditions include moderate temperature of 15 to 25°C.

The solid debris materials of this scenario require special machinery for lifting, and are therefore different from the solids

defined by preceeding scenarios, which may be collected in small volumes by one man. Typically, the large objects are metallic, such as pieces of vessels or damaged storage tanks, or organic, such as logs, plastic sheeting, or debris from wooden structures.

Through interviews with individuals involved in past work with large spill debris, it is noted that oil and chemicals will usually wet the outer surface of objects without appreciably contaminating the inner volume. Exceptions include dry, rotted logs, the inner tissues of which tend to act as a sponge and draw the chemicals to the interior. In general, objects with a void matrix capable of soaking up chemicals, will do so unless the space is already occupied by another fluid, such as water.

The warm air temperature defined by Scenario U does not impact the handling or processing of debris directly; however, chipping of organic objects, or compaction of metallic objects by cutting torch, is not considered safe in the presence of highly volatile chemicals. Under such circumstances, the chemicals must first be washed off the debris so that they no longer present an explosion hazard. Toxic compounds must be neutralized by special washing agents. Handling and disposal of the following chemical groups are considered in association with the solid debris defined by Scenario U:

Chemical Group IVF-I

This group includes two oils: JP-4 and coal tar. Disposal equipment systems for oil Groups IV (JP-4) and V (coal tar) are presented under Scenario S. Disposal equipment systems applied to these oil groups are 12 and 13 (omitting the chipping or torching where sufficient pre-removal of the highly volatile chemicals is not possible).

The 33 floating chemicals in Group IVF-I include many of the short-chain alkane and alkene isomers, as well as gasolines and other light volatile distillates. These materials commonly become associated with bulky debris during spills. There are no toxic floaters included in Group IVF-I.

Review of all chemical-debris mixtures possible under chemical Group IVF-I and Scenario U, indicates that all of them can be handled by systems defined for such oil-debris mixtures: Systems 12 and 13. However, as indicated above, where volatile chemicals cannot be adequately removed from the debris, chipping or reduction with a cutting torch should be omitted. Closed vessels should never be cut with a torch until the nature of the contents can be determined.

Chemical Group IVF-II

None of the oils listed in Appendix A are included in this group, which includes three toxic floaters (TF): turpentine, o-xylene, and p-xylene.

Since Group IVF-II is defined as a collection of volatile compounds, chipping or torching of debris without adequate washing to remove adhering chemicals is not recommended. Systems 12 and 13 are recommended for transporting and disposing of organic and metallic debris spill-masses.

The toxic floaters included in this group should be transported directly to off-site treatment and/or disposal. However, most debris defined by this scenario is not amenable to transport in sealed containers. On-site washing or neutralization of the chemicals, using special washing agents, should be conducted. The personnel conducting the washing and subsequent transport operations must be provided with protective clothing and closed-system breathing apparatus.

Chemical Group IVF-III

Tridecanol, *carnauba* wax, and paraffin are the three floating chemicals comprising this group, which does not include any toxic floaters. The chemicals are highly viscous, but may still adhere to the surface of large debris objects. However, these chemicals will yield to high-pressure steam washings alternated with solvent applications. The chemicals do not appreciably limit the mode of transfer or storage, which is already limited by the bulky nature of the solid debris component. Therefore, disposal Systems 12 and 13 are able to accommodate these chemical-debris spill-mass mixtures. Again, chipping and torching should be excluded, because these compounds are considered volatile and will yield explosive vapors and associated fire hazards during such operations.

Chemical Group IVF-IV

This group is comprised of the oil Group IV: JP-4. See IVF-I above.

Chemical Group IVF-V

This group is comprised of the oil Group V: coal tar. See IVF-I above.

Chemical Group IVF-Oils

All oils in this group are also included in the oil groups considered in Section III of this report. The oil-debris mixtures may be disposed by Systems 12 and 13, except the following oils:

JP-1	Oil: Fuel: No.1
JP-3	Oil: Fuel: No. 1-D
JP-5	Oil: Range
	Kerosene

These oils must not be processed by chipping or torching until adequately removed by washing operations.

Other Chemical Groups

The remaining floating chemicals and debris mixtures considered under Scenario U may all be accommodated by Systems 12 and 13. Compounds which are included in the toxic floaters group (TF) must be removed from large debris items before they are shipped in open trucks or bins to final disposal. Crew personnel involved with removal and/or neutralization of such compounds must be provided with protective clothing and special breathing apparatus.

SCENARIO V - OIL OR FLOATING CHEMICAL/LARGE SOLIDS MIX, STORMY WEATHER, COLD AIR TEMPERATURE

Scenario V is defined as follows:

> Oil or floating chemicals, primarily soaking large solids (pieces of dock, vessels, trees, etc.); stormy weather, cold air temperature.

All chemicals warranting special consideration under this scenario's defined environmental conditions (air temperature at or below 0°C) are included in the group called "Low Temperature Solid Floaters" (LTSF). All these materials are listed as follows:

aldrin (t)	wax-carnauba	asphalt blending-straight run
benzene (t)	wax-paraffin	
tetradecanol	dicyclopentadiene	oils, edible: cottonseed
toluene 2, (t) 4-diisocyanate	Dowtherm	isooctyl alcohol

p-xylene (t)	2-ethyl hexanol	phenol (t)
aniline (t)	isodecyl alcohol	adiponitrile (t)

Some of the chemicals listed above are toxic floaters, as so indicated by a (t). It is therefore determined that only those chemicals included as nontoxic LTSF, and involved in spill masses defined by Scenario V, can be accommodated by the disposal Systems 12 and 13 described in Section III of this report under Scenario S for oils. Others must be handled as hazardous chemicals.

SUMMARY OF SECTION IV

A variety of commercially available equipment is directly applicable to the handling and disposal of recovered oil and floating chemical spill masses. Most equipment may also be used for dealing with floating chemical spill materials, although modification of storage vessels and transfer equipment is necessary to protect crew personnel and the public when volatile and/or toxic chemicals are present.

The same systems described in Task II are also directly applicable to floating chemicals. Some limitations are observed where toxic or volatile chemicals are involved; yet all possible scenarios have at least one system which can be used under the described spill mass and climatic conditions.

V. DISPOSAL TECHNIQUES FOR HAZARDOUS CHEMICALS

INTRODUCTION

Further use is made of the spill disposal scenarios developed in Section II to characterize anticipated debris and environmental condition sets, and to define the operational constraints for hazardous chemical spill disposal equipment systems. Equipment inventories described in Sections III and IV are supplemented by additional equipment items identified in this section which are specially suited to hazardous materials disposal. Previously developed spill disposal systems for handling oils and floating chemicals are utilized as a basis in developing specialized equipment systems for the disposal of hazardous material spills. Conceptualized disposal equipment systems and techniques for hazardous chemicals are recommended for further research and development, based on the inadequacies of existing and modified disposal systems in handling hazardous material spills.

Spill Scenarios for Hazardous Chemicals

The following eight disposal scenarios, as defined in Section II (Table 39) are applicable when considering hazardous chemical spills:

E, F, K, L, Q, R, W and X

Each scenario represents a specific set of expected environmental, fluid and debris characteristics which must be considered in developing or adapting a suitable disposal equipment system.

The maximum anticipated volume of the originally spilled hazardous chemical is assumed to be less than 38 m^3 (10,000 gal), based on data gathered from the literature, personal interviews and other technical sources. Each disposal scenario is described in terms of the expected "worst case" ratio of solid debris or water to the original spill component, with resulting approximate total spill mass volumes as follows:

Scenario	Total Volume	"Worst Case" Ratio of Contaminants to Spilled Component
E, F	76 m^3	(1:1)
K, L	228 m^3	(5:1)
Q, R	3,800 m^3	(100:1)
W, X	5 tons per batch	

TABLE 39. HAZARDOUS CHEMICAL SPILL SCENARIOS (HC)

Scenario	Operational* Conditions	Debris Materials	Spill Volume (m^3)	Transfer Equipment Constraints
E	C - W	HC spilled in water, no natural solid debris. Chemicals may be in solid or liquid state and may evolve to gaseous state during recovery. Typical mixtures of 50 percent chemical and 50 percent water prevail, depending on degree of solubility.	76 (20,000 gal)	None
F	S - C			Positive displ. pump recommended
K	C - W	HC mixed with solids consisting mainly of heavy sludge, soil, sand, sediments, inorganic sorbents. Solid chemicals include those insoluble in water. Typical solid debris/chemical mixture ratios of up to 5 to 1 are anticipated.	228 (60,000 gal)	Solids pump adequate
L	S - C			Requires enclosed tubular conveyor
Q	C - W	HC mixed with large amounts of organic solics (seaweed, storm debris, organic sorbents). Also included are larger particles of insoluble solid chemicals. The ratio of total spill mass to original spill component may verge from 50 to 1 to 150 to 1.	3800 (10^6 gal)	Interim storage (washing, draining)
R	S - C		1900 to 5700 (0.5 to 1.5 x 10^6 gal)	Ice formation introduces a broad recovery time spread
W	C - W	HC soaking primarily large solids (fragments of dock, vessels, trees, etc.). Solid debris also may contain organic or metallic pieces. On-site washing and volume reduction lead to fluids of 76 m^3 (similar to Scenario E) or slurries of 228 m^3 (similar to Scenario K).	Comparable to Scenario E and K	Washing/draining is practical. Results in fluid or slurry similar to E & K.
X	S - C		Comparable to Scenario K	Washing not practical. Transfer directly to volume reduction

*C-W = Calm and warm (0^o - 44^o C)
S-C = Stormy and cold (less than 0^oC)

Spilled hazardous chemicals are expected to combine with water in several different ways, which may be characterized by the following general chemical/water mixture categories:

1. Chemical completely dissolved in water (liquid)

2. Chemical in fine emulsion or colloidal suspension in water (liquid and/or solid)

3. Chemical completely partitioned from water (liquid, solid or gas)

Solid debris in hazardous chemical spills is expected to comprise either a major component to be recovered and disposed of, or a minor contaminant to be removed from waste streams by on-site or off-site treatment. Each disposal scenario is characterized in terms of spill debris size and debris composition, in order to establish the operational parameters for disposal equipment systems. Solid debris is categorized according to the following handling limitations:

1. Pumpable or nonpumpable

2. Grindable or nongrindable

3. Manually liftable or nonliftable.

As previously indicated, spilled hazardous chemicals may exhibit significantly different physical and chemical characteristics from the oils and floating chemicals. Hazardous chemicals are grouped into 17 categories (Appendix C) according to similarities in solubility, volatility-flammability, toxicity, reactivity and physical state, to assist in defining the chemical handling limitations of disposal equipment systems under each scenario.

Special Handling Parameters for Hazardous Chemicals

The special physical and chemical characteristics of the hazardous chemicals defined in Appendix C require special handling and disposal methods to ensure maximum disposal efficiency and minimize hazards to health, property and the environment. Since some of these substances sink, mix with water, or float, they may require specialized handling equipment and techniques. The following is a summary of the special handling problems and methods associated with each of the various chemical groups, defined in Appendix C, excluding any intermixed debris.

Sinking Chemicals (Groups S, VS, TS, TCS, TVS, LTSS)--

Sinking chemicals include both liquids and solids which are insoluble or very slightly soluble in water. The recovered chemical will exist in the original liquid or solid shipping state,

requiring either pumping or conveying transfer capabilities. Under certain conditions, immiscible sinking liquid chemicals may combine with water as a fine emulsion, making separation and concentration of the spilled component difficult. Sinking solid chemicals will be easiest to handle once recovered, requiring only water or solvent washing and draining to remove adhering surface water and debris. A special group of insoluble liquid chemicals, Group LTSS, may be handled as either solids or liquids, depending upon ambient temperature conditions.

Miscible Chemicals (Groups M, CM, VM, VCM, TM, TCM, TVM, TVCM, LTSM)--

Miscible chemicals include both liquid and solid chemicals that are moderately to highly water-soluble at normal ambient temperatures. Normally, sufficient time will have elapsed between the spill event and recovery operations to provide for complete mixing of the soluble chemicals with water. Therefore, only pumping or other liquid transfer capabilities are required for handling of these aqueous solutions. Separation and concentration of the spill component involves removal from solution by means of precipitation, solvent extraction, adsorption, evaporation or other physical/chemical techniques.

Volatile Chemicals (Groups VS, TVS, VM, VCM, TVM, TVCM)--

Volatile chemicals, as defined, exhibit a high vapor pressure and flammability at normal ambient temperatures, resulting in fire or explosion hazards. During handling of these substances, equipment components must be checked to assure the absence of spark-producing ferrous metal-to-metal contacts, electrostatic discharge, or other exposed ignition sources. Transfer equipment involving the flow of volatile chemicals must also be grounded to eliminate the build-up of static charge. Containment vessels which are exposed to heat or direct sunlight must provide a means for accommodating the rapid generation and expansion of gases from the heated chemical, such as internal bladders, floating tank roofs or surge tanks. To the maximum extent practicable, volatile spill materials should be completely contained or enclosed during handling operations to minimize the natural and forced dispersion of flammable vapors. Adequately sized fire-supression equipment, matched to the particular volatile chemical hazard, must be provided at the site of all recovery, transfer and disposal operations.

Toxic Chemicals (Groups TS, TVS, TM, TCM, TVM, TVCM)--

Toxic chemicals are characterized by associated vapors or solid particulate dusts and aerosols which, in very low airborne concentrations, are considered to be harmful to humans. When handling these substances, complete containment is of utmost importance in preventing the spread of toxic vapors to adjacent populated areas and in minimizing health hazards to members of the disposal crew. Containment vessels must provide a gas and liquid-tight seal to prevent escape of toxic materials, and no

external venting can be permitted. Incineration will not usually be acceptable for toxic substances without stack gas processing to reduce noxious emissions. Disposal crew members must be provided with appropriate NIOSH-approved personal protective equipment whenever uncontained toxic materials are being handled.

Caustic Chemicals (Groups TCS, CM, VCM, TCM, TVCM)--
Caustic chemicals tend to be reactive with many common construction materials causing substantial corrosive damage to unprotected equipment surfaces. Protective clothing, including gloves, face shields, and acid suits is required when handling these materials to prevent possible injuries to human tissue. Compatible, corrosion-resistant materials or special impervious coatings must be used on all "wetted" or contacting equipment surfaces to prevent hazardous reactions or greatly accelerated rates of corrosion and wear. Dilution or neutralization of caustics is often advisable before attempting transfer, treatment or disposal of spilled wastes to reduce health and environmental hazards.

Gaseous Chemicals (Groups G, DG)--
Gaseous chemicals are those substances which at normal ambient temperature and pressure exist as a distinct gas phase which is not water-soluble. Gases may or may not be recoverable using conventional collection techniques, depending on the vapor density in relation to air. Lower density (lighter than air) gases will normally disperse and become diluted in air via the mechanisms of buoyancy and air movement. Heavier gases will tend to "float" slightly above impermeable water or ground surfaces, and may be recoverable if appropriate containment and collection techniques can be devised. Vapor transfer capabilities are required for the movement of gaseous products, normally in the form of flexible ducting and differential pressure or flow-inducing devices such as compressors or fans. Containment of gaseous waste products requires the use of vapor-tight low-pressure rated vessels to prevent the escape of recovered vapors.

General Hazardous Waste Treatment and Disposal Methods

The following discussion of methodologies is summarized in Table 40.

Incineration--
Incineration is defined as a controlled oxidation process for the detoxification, volume reduction or destruction of liquid, solid and gaseous organic wastes, and the thermal degradation of some inorganics. Complete incineration destroys the organic fraction of waste materials, resulting in an inorganic ash, gaseous by-products and volume reduction of solids of up to 90 percent. Incineration can eliminate the toxic or hazardous properties of wastes, when such properties are due to the organic molecular structure, by thermally destroying the organic fraction.

TABLE 40. GENERAL HAZARDOUS WASTE TREATMENT AND DISPOSAL METHODS

Class	Process	Currently* Used	Adaptable*
Incineration	Volume reduction	x	
Physical (e.g., grinding, chipping, etc.)			
Filtration	Phase separation	x	
Liquid separation		x	
Liquid/solid separation		x	
Dewatering		x	
Washing/dilution		x	
Carbon sorption		x	
Ion exchange		x	
Flocculation		x	
Neutralization		x	
Chemical fixation		x	
Oxidation/reduction		x	
Precipitation		x	
Chelation			x
Aerobic-biological	Biological	x	
Anaerobic-biological	Treatment	x	
Landfilling	Land	x	
Land burial	Disposal	x	
Land cultivation			x
Deep well injection			
Ocean dumping	Miscellaneous		
Engineered storage		x	
Recovery/reuse		x	

This makes incineration an effective means of pretreatment for hazardous materials prior to land disposal, minimizing adverse environmental impacts (36).

Incineration is considered one of the most effective means of treating and disposing of a wide range of hazardous materials with a minimal impact on the environment, and is particularly applicable to nonbiodegradable and restricted organics. It is estimated that, with proper emission control techniques, approximately 60 percent of all designated hazardous materials can be destroyed by incineration (14).

Although routinely used throughout industry in stationary applications for destroying combustible wastes, incineration of hazardous material spill residuals on-site is a relatively new technique. A mobile field use incinerator system currently being developed by MB Associates for EPA, Edison, New Jersey, is trailer-portable to the spill site and incorporates extensive secondary abatement equipment to minimize hazardous emissions. The unit is capable of destroying or detoxifying most organic hazardous compounds in solid, liquid or slurry form, with the exception of certain inorganics and heavy metal compounds. Sea-going incineration of hazardous materials is also possible, as demonstrated by the disposal of approximately 17,000 metric tons of liquid organochlorine wastes by the M/T Vulcanus, a converted cargo ship, in 1974-75 (16). Shipboard incinerator units such as the Vulcanus would be capable of destroying practically any spill mass volume on-site, eliminating the need for transfer to shore-side facilities and the risk of a secondary spill. Smaller, less complex portable incinerator units are also available for on-site use. These units will normally be adequate only for less hazardous materials since they lack the flue gas processing equipment necessary to achieve "clean" emissions.

Filtration--

Filtration involves the physical removal of solid particulates from the fluid waste stream by passing through a selectively porous filter media or membrane. Most filters also depend on the formation of a cake of solid particles on the filter media as a secondary barrier to the passage of solids.

Filtration equipment includes conventional, reverse osmosis, inertial, ultra and micro-filters, with many different media or membrane types and respective modes of operation. Ultrafiltration is capable of removing particles which are between 0.003 and 1 microns in size, while conventional filters operate in the particle size range of 3 to 5 microns or larger. Applications of filtration equipment at hazardous spill sites have typically been conventional mixed-media, gravity-flow filter columns intended for the removal of precipitates and other suspended solids from waste streams. The U.S. EPA Hazardous Materials Spills Treatment Trailer incorporates this form of

filtration as a pretreatment to remove precipitated and suspended particulates from fluid wastes prior to submittal to carbon sorption columns. Gravity-flow filter columns containing a top layer of powdered anthracite over a bed of red flint sand are used in this unit (26). Membrane filtration techniques, such as ultra-filtration or reverse osmosis, also appear to be adaptable to on-site fluids treatment.

Liquid/Liquid Separation--

Liquid separation involves isolation of two or more liquid phases as a means of volume reduction, waste concentration or removal of contamination from aqueous effluents. The most common form of liquid separation is oil/water separation, the removal of free or emulsified oils from the water phase. Oil/water separators are not effective in removing soluble oils or some very fine emulsions from water. The three basic types of oil/water separators (gravity, plate, and coalescing) are also applicable to some immiscible hazardous liquids which exhibit physical and chemical characteristics similar to oils. Portable oil/water separator units are readily available for on-site treatment of these oily hazardous materials.

Separation of other nonsoluble hazardous fluids is possible using a liquid/liquid separator unit. One commercially available unit of this type utilizes a gravity-assisted coalescing technique to separate up to three immiscible liquids of differing specific gravities.

At present, no commercially available portable unit exists for the physical separation of miscible hazardous materials from the water phase. Separation of miscible liquids from solution can normally be accomplished by chemical or physiochemical treatment methods such as precipitation, neutralization, carbon sorption, ion exchange and others.

Liquid/Solid Separation--

Various physical processes exist for the separation and removal of solid particulates from aqueous waste streams. One of the most common and effective forms of liquid/solid separation is filtration. Other separation methods include centrifugation, flocculation, sedimentation, and air flotation devices. Of these, the most applicable methods for portable, on-site liquid/solid separation of hazardous materials from water are centrifugation or a combination of flocculation and sedimentation. The latter two methods are utilized in a rapidly deployable tank immediately preceding carbon sorption columns in the U.S. EPA Hazardous Materials Spills Treatment Trailer.

Dewatering--

Dewatering is used here to describe a physical process for the removal of absorbed or adhering water from solid chemicals, sludges and contaminated debris. Current methods utilized for

solids dewatering include vacuum drum filtering, sludge concentrators or presses, screening and draining. Of these methods, screening and draining are probably the most commonly used for gravity-assisted dewatering of hazardous material solids and contaminated debris. On-site dewatering of sludges can be performed using one commercially available sludge concentrating unit which is trailer-portable to the spill site. This dewatering unit has both gravity and pressure dewatering capabilities, and a flash-mix polymer mixer for flocculation or thickening of influent sludges.

Water Wash/Dilution--

A spill countermeasure consisting of water sprays or fogs is very frequently used to wash materials contaminated with hazardous chemicals or to "knock-down" and control hazardous vapors. Water washing may also be used to intentionally dilute hazardous material spills to facilitate further treatment. According to a recent study of hazardous material spills reported between December 1975 and May 1976 by EPA, water washing was the most frequently used method for treating hazardous material spills (14).

Volume Reduction--

Various physical processes for reducing the overall volume of heterogeneous debris are employed to facilitate more efficient transfer, storage, treatment and disposal. Numerous types of volume reduction equipment are commercially available, including shredders, chippers, balers and compactors.

Shredders and chippers use rotating hammermills or knives to tear, crush or cut materials, converting heterogeneous debris into a homogeneous mixture of fines, chips or shredded matter which can more readily be handled for treatment and disposal. The use of shredding or chipping for volume reduction of spill masses containing large amounts of organic matter or other debris may also make possible the use of conventional industrial waste treatment techniques which would otherwise be impractical. Portable chipping and shredding equipment is available from several commercial sources for on-site use, and is commonly used for volume reduction of organic solids such as tree limbs, logs, dead leaves and earthen materials during land-clearing operations.

Balers and compactors make use of large mechanical or hydraulic forces acting through packing blades or plates to compact solid materials to the minimum practical volume. Compaction of solid waste greatly enhances its transportability, and results in a reduction of the area required for storage or disposal of the waste mass. Portable compacting units and self-propelled compacting trucks practical for on-site use are generally available from a multitude of commercial sources. All but the smallest capacity baling units are intended for stationary use, and are not practical for on-site applications. Portable

compacting units and vehicles are very commonly used for solid waste management in the industrial, commercial and residential sectors.

Carbon Sorption--

A process for the removal of dissolved organic materials from solution in aqueous effluent, carbon sorption is a process by which adsorption onto the surface of activated carbon powder or granules takes place. Wastewaters are passed through granulated carbon in up- or down-flow columnar beds, or mixed with powdered carbon and separated by filtration. Granulated carbon columns are more commonly used since the spent carbon can economically be regenerated for reuse. Carbon sorption is particularly effective in treating wastes that are not amenable to biological degradation due to their toxicity or dissolved refractory organics (27).

Carbon sorption has been used for many years to remove organic and other contaminants from municipal water, and to clean industrial waste streams. A more recent application of this technology is portable carbon sorption units for on-site treatment of hazardous chemical spills, such as the U.S. EPA Hazardous Materials Spills Treatment Trailer, developed by EPA's Industrial Environmental Research Laboratory. This trailer-mounted road-portable unit incorporates granular activated carbon columns for the removal of many soluble organic chemicals. The effectiveness of this portable unit was demonstrated in the treatment of approximately 850,000 ℓ of kepone-contaminated washdown and run-off water in Hopewell, Virginia, in 1976 and in various other incidents (27). Removal of soluble toxic compounds by the Hazardous Materials Spills Treatment Trailer has exceeded 90 percent for all but two of the toxic compounds encountered thus far (26). Other mobile facilities include the CALGON Mobile Treatment Service. This system appears to have certain attractive features:

- It is a contracted mobile clean-up service, thus avoiding extensive capital expense
- Can handle flow rates of 660 ℓ/hr (250,000 gal/day)
- Regeneration of spent carbon is part of service contract.

Ion Exchange--

This chemical process involves the reversible interchange of ions between a solid resin and soluble hazardous materials in the liquid phase. Ion exchange resins are available as either weakly or strongly acidic cation or basic anion exchangers. Ion exchange technology has been available for many years for the detoxification and removal of hazardous metal ions and cyanides from industrial waste streams. Contaminants removed from solution can be recovered in many cases by regenerating the exchange

resins with a concentrated reverse flow of ions, or safely disposed of by various methods.

Flocculation--

Flocculation is a physicochemical process for removing minute contaminants from colloidal suspension in waste streams through the addition of chemical flocculating agents and physical agitation of the fluid medium. Colloidal particles are chemically induced to coalesce or aggregate into larger, more easily removable solids. Flocculation has been extensively used in treating municipal and industrial waste streams, and is adaptable to on-site treatment of spill residuals by using portable, field-erectable tanks and manual or powered stirring devices. The U.S. EPA Hazardous Materials Spills Treatment Trailer uses flocculation as a pretreatment prior to filtration and carbon sorption.

Neutralization--

The addition of acidic or alkaline substances to hazardous materials is employed to achieve a nearly-neutral (pH = 7) mixture. The same effect can be produced by passing the spill mixture over a bed or bubbling through a tank of acidic or alkaline material. Neutralization is also effective for the precipitation of solids from solution, including some dissolved heavy metals.

Neutralization of spilled hazardous materials is very often performed *in situ* by the addition of acids or bases to contaminated soil, water or debris (14). Limestone, lime and soda ash are normally used for treating acid spills, while hydrochloric or other acids are used in neutralizing alkaline spills.

Oxidation/Reduction--

A process in which an oxidant interacts with a reductant to convert a waste to a less hazardous state may be referred to as oxidation or reduction. Oxidation commonly involves the use of chlorine, ozone, hydrogen peroxide or hypochlorites to treat cyanides or other reductants. Sulfur dioxide, ferrous sulfate, sulfite salts or other reducing agents are typically used to treat waste streams containing oxidants such as chromium-6.

Precipitation--

The reaction of two water-soluble reagents to form an insoluble compound yields a precipitate in the form of a disposable sludge, gel or solid. These solids normally coagulate into larger solid aggregates which may be removed from water by physical methods such as filtration, centrifugation, sedimentation or flotation. Precipitation is a means of separation and volume reduction by concentrating and removing hazardous contaminants from water. The reaction also detoxifies the solution by reducing the level of dissolved hazardous substances.

Chelation--

Chelation is a chemical process in which a synthetic or natural chelating agent is added to bind up hazardous metal ions in solution, reducing their toxic effects. Chelating agents can be either synthetic or natural, but are generally organic, and may react selectively with one or several metal ions.

Chemical Fixation--

Various proprietary chemical fixing substances, which react with hazardous materials or themselves, form a chemically and mechanically stable solid. The process is used to detoxify hazardous material spill residues prior to transfer or disposal operations. Chemical fixation is particularly applicable to highly concentrated and hazardous wastes which cannot be effectively treated using conventional industrial waste treatment techniques.

Biological--

A biological detoxification process for organic wastes uses biologically active growths in the presence (aerobic) or absence (anaerobic) of oxygen. Varios biological degradation methods include municipal treatments such as activated sludge, trickling filters, aerated lagoons, waste stabilization ponds and package biological treatments such as fluidized-bed biodegradation. Of these methods, only fluidized bed biodegradation and waste stabilization ponding are practical for portable, on-site treatment of hazardous materials.

Biological treatment of a great many organic hazardous materials is possible, although pretreatments such as dilution, neutralization or liquid separation may be required in some cases to allow efficient biological growth rates. Biodegradation is a relatively slow process, with the possible exception of fluidized-bed biodegradation, and requires an influent waste stream with a narrow range of flow, composition and concentration characteristics. Toxic materials can only be biodegraded in very dilute concentrations due to the risk of destroying the biological treatment culture. Some work has been conducted to determine the biodegradability of various spilled hazardous materials (31).

Landfilling--

In an engineered land disposal method, wastes, including hazardous materials, are either mixed with soil, buried in shallow pits, or handled by some combination thereof. Landfill sites are classified into two general categories, sanitary landfills and chemical landfills, based primarily upon the type of wastes accepted and the protection provided against potential contamination of air and ground or surface waters.

Sanitary landfill sites normally accept only municipal solid wastes and other insoluble, inert waste materials. Hazardous wastes may be accepted for disposal if properly pretreated

and/or containerized to neutralize hazardous properties. Untreated hazardous materials will only be acceptable for disposal at approved sanitary landfill sites in very small quantities. Sanitary landfill sites are specially selected, designed and operated to minimize the leaching of waste residuals into adjacent surface or ground waters, although no collection or treatment of leachates is usually required. Wastes are spread into thin layers and compacted, with cover material applied at the end of each working day to minimize environmental hazards. Sanitary landfilling, in other than specially approved sites, is not a recommended disposal method for most hazardous wastes due to the potential for leachate contamination of groundwaters, generation of hazardous vapors or explosive chemical interactions.

Chemical landfill sites, also called secure or approved landfills, are designed to accept almost all hazardous materials for disposal with a minimal risk of environmental damage. Chemical landfill sites are specially selected with respect to geological and hydrological features to avoid any direct hydraulic connection between landfill leachates and adjacent ground or surface waters. In some cases, ground and surface water flows must be completely redirected around the landfill site. Chemical landfills typically incorporate elaborate drainage control systems for the collection of leachate, which are often treated by neutralization, biodegradation, evaporation or precipitation, and the residuals returned to the landfill (45). In geographic areas where low-permeability soils do not naturally occur, impervious basins using natural or artificial liners of clay, rubber, asphalt, concrete, plastics, or other materials may be used to isolate and contain disposed wastes and prevent contamination of usable water resources. Wastes are normally segregated into cells and the disposal coordinates recorded to prevent any possibility of explosive or toxic chemical interactions by accidental mixing. A comprehensive sampling and analysis program, including the drilling of landfill monitoring wells, is performed at most hazardous disposal sites to help control any possible air or water pollution resulting from landfill operation. Pretreatment of persistent or especially hazardous materials is often necessary to ensure safe, long-term landfill disposal. Safeguards include chemical fixation, containerization, plastic or concrete encapsulation in drums or any of the various chemical or biological treatment methods. Wastes may also be encapsulated in bulk by utilizing clay, plastic, or asphalt covers or "caps" over the entire finished landfill to prevent rainwater saturation and erosion. The landfilling of highly toxic or volatile wastes requires the immediate application of cover material, in contrast to the daily cover of municipal wastes in sanitary landfills.

The chemical or secure landfill has the widest applicability to the land disposal of hazardous wastes, although suitable sites may be remotely located from the scene of many hazardous

material spills. The sanitary landfill site is more common and likely to be much more conveniently located to the spill scene, but will accept only hazardous materials that have been adequately pre-treated to neutralize any hazardous properties. Locations and capabilities of facilities which accept hazardous materials for land disposal may be determined by referring to the latest revision of a directory (30) published by the U.S. Environmental Protection Agency, Hazardous Waste Management Facilities in the U.S.

Land Burial--

If properly executed, land burial can be an ultimate land disposal method for highly hazardous materials which require permanent containment. Disposal is presently only accomplished using near-surface burial, although preliminary studies are being conducted concerning the use of deep burial in salt formations and hard bedrock (27). Wastes are deposited either directly into impervious soil or clay-lined cells or into stainless steel tanks or concrete-lined and covered pits. Near-surface burial of hazardous materials is currently being practiced at several commercially operated disposal sites throughout the United States.

Land Cultivation--

This is a process in which organic wastes are spread in thin layers on tilled land and thoroughly mixed with soil to promote aeration and biological degradation. Land cultivation is limited to biodegradable materials with low toxic concentrations and an average debris size of 7 to 10 cm or less. Optimum land cultivation sites are located in areas with an adequate soil depth and a low water table and should be well removed from any useable water supplies. A warm climate with moderate precipitation and evaporation rates will facilitate the most rapid biodegradation of wastes, although land cultivation has been shown to be effective in cooler, less ideal climates.

Most applications of land cultivation techniques have been for the disposal of oils and other hydrocarbon wastes initially, and still primarily, by the oil industry. Some recent applications, such as the land cultivation disposal of acidic, oily wastes containing various heavy metal contaminants in Utah (61), have demonstrated the effectiveness of the technique in degrading hazardous materials. In some cases, the receptor soil must be chemically pretreated prior to land cultivation to adjust pH level and supplement the available phosphorus and nitrogen nutrient levels to ensure complete and effective biodegradation of hazardous materials. Land cultivation may be a viable on-site disposal alternative for hazardous materials spills if an appropriate land area can be semi-permanently dedicated to this purpose.

Deepwell Disposal--

Deepwell disposal is defined as a disposal process for raw or treated liquid wastes which are filtered and injected under pressure into deep wells where they disperse into permeable subsurface rock. Injection wells ideally are isolated by impermeable rock or clay layers to avoid possible contamination of fresh water supplies. Highly hazardous materials must be chemically or physically detoxified prior to injection. Wastes containing suspended solids or other particulate matter are pretreated for solids removal to prevent clogging of the porous disposal stratum.

Deepwell disposal has been most extensively used by the oil and gas industry to dispose of waste oil field brines. More recently, the chemical, pharmaceutical and other industries have made use of this technique to dispose of various waste products (27). The availability of suitable deepwell disposal facilities is somewhat limited and geographically concentrated in the south and southwestern portions of the United States, making transport of spilled hazardous materials for disposal inconvenient and expensive in some cases.

Ocean Dumping--

An ultimate disposal method for all forms of bulk and containerized waste materials is ocean dumping, generally unacceptable due to its adverse environmental impacts. Liquid and slurry-type wastes are often dumped directly off barges to sink, diffuse or dissolve throughout the water column. Other more hazardous materials are containerized in sealed or unsealed tanks, drums or vessels and dumped to sink at sea.

Ocean dumping of various wastes is regulated under a permit system administered by the U.S. EPA, provided for by the Ocean Dumping Act of 1972. In general, residual materials from spills of hazardous chemicals will be prohibited from ocean disposal unless properly treated or encapsulated.

Engineered Storage--

This is described as a long-term storage method for very hazardous materials which cannot be safely disposed of using available disposal techniques. Engineered storage is designed to allow safe storage of hazardous materials for an indefinite length of time, yet provide immediate access for retrieval of wastes at some future date. The intention of engineered storage is to safely store hazardous wastes until such a time that an environmentally acceptable disposal method can be developed, or until a suitable disposal site can be located. At present, engineered long-term storage is being proposed for high-level and certain low-level radioactive wastes (27). Engineered storage includes an annually scheduled review of presently available disposal technology and regular maintenance/replacement of disposal containers.

Recovery/Reuse--

Recovery/reuse is a technique for minimizing the disposal costs and environmental impacts of hazardous material spills by recovering easily separable waste products for reuse, resale or exchange. Recovery of valuable or highly hazardous materials from waste streams may be accomplished by various physical, biological or chemical separation processes, but only the simplest, most cost-effective techniques are practiced in lieu of other disposal alternatives. For certain highly hazardous materials, recovery may be justified regardless of cost, due to environmental considerations.

Many hazardous materials, such as ammonia or mercaptan, can be separated from waste streams using various simple recovery techniques, and subsequently reused for their original purpose. Recovered materials may prove to be slightly lower in chemical integrity, but can be restored to reusable quality by blending with quantities of new chemical product. Organic chemical wastes may also have some value for use as a fuel, with heating values approaching or surpassing that of natural gas (70).

A limited number of recovered wastes may be valuable enough to consider for resale, mainly for fuel or other uses. In this case, the total monetary benefit of chemical recovery for resale would be determined by adding the alternative cost of disposal to the sale price (70). In some regions, nonprofit and other organizations can arrange confidential waste exchanges between interested parties to avoid the costs of hazardous material disposal.

Off-Site Disposal--

Some of the general disposal methodologies are practiced by off-site contractors. Figure 29 shows how these methodologies may be applied to different hazardous chemical groups as defined in Appendix C.

Applicability of Existing Disposal Systems to Hazardous Chemicals

Those disposal systems proposed in Sections III and IV, for oils and floating chemical groups, may be adapted to the groups of hazardous chemicals by implementing a variety of system modifications. The recovery, transfer, storage and disposal operations peculiar to the handling of certain hazardous chemicals can bear close resemblance to those used in the processing of spilled oil and floating chemicals. Definition of previous systems 1 through 13 and OS-1 through OS-4, together with their applicabilities to and the limitations or constraints imposed by hazardous chemicals, are given in Table 41.

The systems previously proposed for oils and floating chemicals are revised for handling hazardous chemicals as shown

			SCENARIOS															
			A	B	C	D	G	H	I	J	M	N	O	P	S	T	U	V
DISPOSAL METHODS	Pre-Processing	Re-refining	X	X	X	X												
		Blending with fuel oils	X	X														
		Road oils	X	X														
		Demulsification	X	X	X	X	X	X	X	X								
		Oil/water separation	X	X	X	X	X	X	X	X								
	Treatment	Chemical treatment	X	X	X	X	X	X							X	X	X	X
		Filtration			X	X	X	X	X	X								
		Biological treatment					X	X	X	X								
		Sludge dewatering					X	X	X	X								
	Disposal	Lagooning	X	X	X	X	X	X	X	X								
		Incinerators, scrubbers, & stack emissions	X	X	X	X					X	X	X	X	X	X	X	X
		Landfilling with refuse					X	X			X	X	X	X				
		Land cultivation					X	X	X	X								
		Burial					X	X	X	X	X	X	X	X				
		Incorporation into roadbed	X	X	X	X												
		Ocean dumping																
		Shredding, chipping, & grinding					X	X	X	X	X	X	X	X				

FIGURE 29. CONTRACTED DISPOSAL AT OFF-SITE FACILITIES: DISPOSAL MATRIX BY SCENARIO.

TABLE 41. APPLICATION OF EXISTING DISPOSAL SYSTEMS TO HAZARDOUS CHEMICAL SPILL DEBRIS

System	Scenarios	Definition*	Applicability to Hazardous Chemicals (See Appendix C)	System Limitations (See Appendix C)
1	E and F	Fluids transferred from on-site processing to on-board storage and disposal by seagoing incinerator.	All anticipated spill sizes without equipment capacity changes. Slightly over five days continuous burning required for disposal by incinerator at the specified burn rate. Groups S, LTSS†, M, LTSM†, except for insoluble solids.	Concentration of miscible or water-soluble chemical prior to incineration by on-site treatment is recommended (System OS-3) Groups VS, TVS, VM, VCM, TVM, TVCM, are too flammable for on-board incineration. Groups TS, TCS, TM, TCM, can generate noxious emissions. Groups CM, TCM, VCM, TVCM, attack refractory material in incinerator chambers, stacks.
2	E and F	Fluids transferred to vacuum tankers, towed to shore for on-site treatment or transport to off-site facility for disposal.	No equipment capacity changes Groups S, LTSS†, M, LTSM†, except for insoluble solids, without equipment modification Volatile wastes,provided transfer equipment is properly grounded.	Toxic wastes require crew members to be equipped with self-cpntained breathing apparatus (Item 2203) Handling of caustic wastes requires protective gloves, face shields and acid suits (Items 2201 and 2202).
3	E and F	Fluids transferred to waste chemical tanks or drums which are moved to on-site processing or to off-site treatment/ disposal.	No equipment capacity changes Groups S, LTSS†, M, LTSM†, same as System 2 Volatile wastes - same as System 2 Venting required in chemical tanks to avoid explosion risks.	Toxic wastes require self-contained breathing apparatus, as in System 2. Containers and transfer equipment are required to be sealed liquid-and air-tight Caustic wastes require protective clothing, as in System 2. Portable tanks - Tp. 316 stainless w/liner.
4	E and F	Fluids transferred to flexible storage bag or "donut". Towed to shore for on-site processing or off-site disposal.	No equipment capacity changes Groups S, LTSS†, M, LTSM†, same as System 2 Volatile wastes - same as System 2 Venting required in chemical tanks to avoid explosion risks	Not applicable to toxic wastes. These are best handled by System 3. Since caustic wastes present the possibility of 'holing through' the towable flexible storage bags and would require extensive modification to 'donuts', they are best handled by other systems.

TABLE 41 (continued)

System	Scenarios	Definition*	Applicability to Hazardous Chemicals (See Appendix C)	System Limitations (See Appendix C)
5	K and L#	Spoils from recovery vessel or off-shore dredge discharged into portable tanks, pipeline to shore, or barge with raised gunwales. Transferred into vacuum tankers or portable drums for transport to off-site disposal.	Minor modifications in equipment capacity (addition of 34 portable waste tanks, Item No. 304). Groups S, LTSS, M, LTSM, without equipment modification. Volatile wastes - same as System 2. Venting required in chemical tanks to avoid explosion risks.	Temporary storage tanks (Item No. 302) or barge deck should be protected by impervious liner (Item No. 118), compatible with chemical to be handled. Portable tanks, pumps and vacuum tankers should be constructed of Type 316 stainless steel, for corrosion resistance.
6	K and L#	Similar to System 5, with addition of liquid/solids separation. Pumpable solid effluents from separator to additional on-site treatment.	No equipment capacity changes. Groups S, LTSS, M, LTSM, without equipment modification. Volatile wastes, provided transfer equipment is properly grounded.	Not applicable to handling of toxic chemicals. Best handled by System 5, using sealed, portable waste tanks. Liquid/solid separation is bypassed to avoid fire/explosion risk. Collapsible 'pillow' tanks (Item No. 201) proposed for temporary on-site storage.
7	K and L#	On-shore transfer of contaminated soils to lined dump trucks. Recovered slurries are passed through a liquid/solids separator. Liquid effluents are then transferred by vacuum tanker to off-site disposal.	Minor modifications in equipment capacity (addition of 19 open-top roll-offs (Item No. 511). Groups S, LTSS, M, LTSM without equipment modification. Toxic materials in slurry form can be handled by pumping directly into collapsible pillow tanks.	Sand and soils contaminated by highly flammable (volatile) chemicals present a fire/explosion risk. Such debris best left in place isolated from ignition sources, to weather naturally. Residual materials can subsequently be disposed of by methods similar to System 7.
8	Q and R	Spill mass loaded into portable bins, barge or small skows for transfer to shore. Liquid effluents from optional on-board separation transferred to shore as in Scenario E. Debris on barge stockpiled temporarily on shore or placed into lined dump trucks. Bins and skows onto flat bed trucks. Transport to disposal site.	All anticipated spill sizes without equipment capacity changes. Groups S, LTSS, M, LTSM, without equipment modification. Caustics may be accommodated through use of membrane liners to protect metallic surfaces of tank, dump trucks, bins, skows, barges.	Toxic and volatile wastes that adhere to the spill mass require 12 open-top roll-offs (Item 511), equipped with gasketed top to contain vapors. Toxins necessitate self-contained breathing apparatus, as in System 2.

TABLE 41 (continued)

System	Scenario	Definition*	Applicability to Hazardous Chemicals (See Appendix C)	System Limitations
9	Q	Spill mass placed in barge equipped with membrane liner. Washing, screening, and draining on shore, liquid effluent submitted to on-site treatment. Solids are stockpiled or loaded into bins for transportation to off-site facilities.	Same as System 8.	Same as System 8.
10	Q and R	Spill mass, consisting mainly of small wood solids, collected in the same way as in System 9, is transferred to shredder or chipper and the reduced mass processed as in Scenario K, or transported to an off-site disposal facility.	All anticipated spill sizes without equipment capacity changes. Groups S, LTSS, M, LTSM without equipment modification.	System not directly applicable to handling of caustic debris due to possibility of corrosion damage to internal components of chipper and shredder machinery. Volatiles may create explosion/fire risk during volume reduction operations. Toxic wastes not compatible with volume reduction operations due to lack of proper vapor containment.
11	Q	Composite of Systems 9 and 10: On-shore washing and draining, separation of wood solids and later submittal to shredding and chipping operations.	No equipment capacity changes Groups S, LTSS, M, LTSM, as above. Caustic-soaked debris requires that liners, pumps, hoses be selected for compatibility with and corrosion resistance for specific chemical being handled.	Same as System 8. (With additional recommendation that caustic debris be thoroughly washed with solvents, high-pressure steam, etc., prior to volume reduction).

TABLE 41 (continued)

System	Scenario	Definition	Applicability to Hazardous Chemicals (See Appendix C)	System Limitations
12	W and X	Large wood solids from off-shore recovery are transferred to shore by PRV or barge to be stockpiled on liners. Large objects are washed** to remove adhering chemicals and liquid washings are transferred to on-site treatment or disposal (Scenario E or K). Solids are processed by chipping or splitting or, if sufficiently clean, returned to environment. Reduced debris is temporarily stored to await transfer to on-site or off-site processing.	Disposal of large objects, in batches weighing up to 5 tons each. Handling of large solid debris, soaked or coated with chemicals from groups S, LTSS, M, and LTSM. Adherent caustics require modifications to provide corrosion resistance and prevent release of caustic fluids. Volatile wastes require washing** with water, high-pressure steam or solvents. Toxic wastes washed** prior to volume reduction require a second washing. Self-contained breathing apparatus must be supplied crew members involved in volume reduction operations.	As with oil and floating chemical disposal operations, a weight limit of 5 tons per debris transfer is imposed due to work boat capacity and crane lifting capabilities. In the handling of debris coated with caustics, membrane liners are required as an addition to the basic equipment of this system for protection and prevention of leakage. For very permeable (highly porous) debris, to which flammable wastes have adhered, volume reduction by chipping or splitting should be avoided in order to minimize risk of fire or explosion.
13	W and X	Large metallic solids from off-shore recovery transferred to shore to be stockpiled on liners. Large objects washed** - liquid effluent transferred to on-site treatment or disposal (Scenarios E or K). Solid debris is stockpiled, metals being submitted to torch-cutting for volume reduction, stored prior to transfer to on- or off-shore processing.	Same as System 12.	As with oil and floating chemical disposal operations, a weight limit of 5 tons per debris transfer is imposed due to work boat capacity and crane lifting capabilities. In handling of debris coated with or adhered to by caustics, membrane liners are required as an addition to the basic equipment of this system for protection and prevention of leakage.

TABLE 41 (continued)

System	Scenarios	Definition	Applicability to Hazardous Chemicals (See Appendix C)	System Limitations
OS-1	E,F K,L Q,R W,X	Incoming liquids from recovery or preprocessing are pumped to one of the following subsystems: • Temporary storage tank • Demulsification • Liquid/liquid separation Aqueous effluent is monitored, returned to watercourse. Concentrated wastes are transported to off-site facilities.	Any anticipated volume of liquid effluents from Scenarios E, K, Q or W without change in equipment capacity. 380,000 liters of wastes processed in 4 hours continuous operation. Applicable to liquid effluents containing chemicals from Groups S and LTSS.	Not applicable to highly viscous and concentrated chemical effluents for which liquid/liquid separation is not feasible. At lower temperatures (Scenario F, L, R and X) group LTSS is nonpumpable due to semi-solid state. Not applicable to miscible chemicals in solution. These best handled by System OS-2.
OS-2	E,F, K,L Q,R W,X	Incoming liquids processed as in System OS-1, further processed by: • Chemical treatment • Biological treatment • Physical treatment Aqueous effluent monitored, discharged solids stored, dewatered, disposed on-site or transported off-site.	No increase in equipment capacities. Hazardous characteristics of toxic, volatile or caustic wastes can be neutralized by various combinations of physical, chemical or biological treatment.	At lower temperatures (Scenarios F, L, R and X), groups LTSS and LTSM are nonpumpable due to their semi-solid state.
OS-3	E,F K,L Q,R W,X	Incoming liquids are processed as in System OS-1. Concentrated effluents are burned in a portable on-site incinerator.	No increase in equipment capacities. Applicable to Groups S, LTSS, M and LTSM in Scenarios E, K, Q or W. Burn time of about 3.5 days required to dispose of 43,000 liters of liquid waste. Volatiles can be incinerated if fire-suppression equipment is available.	Not suitable for on-site incineration of toxic fluids due to generation of unacceptably noxious emissions. At lower temperatures (Scenarios F, L, R, and X) Groups LTSS and LTSM are nonpumpable due to their semi-solid state.

TABLE 41 (continued)

System	Scenarios	Definition	Applicability to Hazardous Chemicals (See Appendix C)	System Limitations
OS-4	E K Q and W only	Incoming liquids from recovery or preprocessing are placed in temporary storage. Wastes are later disposed of by on-site land cultivation. Disposal site is analyzed and monitored for potential contamination.	On-site land disposal of liquid wastes containing Groups S, LTSS, M, and LTSM. Scenarios E, K, Q or W only. Volatile, toxic and caustic waste liquid, if very dilute - otherwise best treated by Systems OS-1 or OS-2 prior to off-site disposal.	Not applicable to disposal of waste containing LTSS or LTSM under Scenarios F, L, R or X. These semi-solids cannot be land applied by cultivators designed for subsoil injection.

*Includes pumpout of primary recovery vessel and optional demulsification, or liquid/liquid separation.

†These chemicals tend to solidify at low temperatures. Systems 6 and 7 indicated.

‡In cold weather conditions, pumping techniques involving hoses or pipelines are not practical. Instead, the use of the enclosed tubular conveyor (Item No. 903) is recommended.

**Washing is not practical in cold weather (Scenario X).

use, and are not practical for on-site applications. Portable

available for many years for the detoxification and removal of hazardous metal ions and cyanides from industrial waste streams. Contaminants removed from solution can be recovered in many cases by regenerating the exchange

in Table 42. This table presents tabular data proposing changes in terms of equipment design, capacity, additions to inventory, etc., required to adapt the existing systems to the processing and disposal of spill mass containing hazardous chemicals.

Volatile hazardous chemicals and debris, for example, pose problems with respect to ignition from sparks generated by heavy equipment or improperly grounded transfer equipment such as pumps. The use of collapsible rubberized fabric pillow tanks for temporary vapor-tight storage of volatile spill mass is an instance of such a system modification proposed for System 6. Three Aero-Tech Labs Model 120770-H (Item No. 201) pillow tanks, each having a capacity of about 76,000ℓ (20,000 gal), provide temporary on-site storage for up to about 228 m^3 of volatile wastes. Additional capital costs, including ground cloths and covers resistant to ultra-violet radiation, are estimated to be about $29,000.

Toxic chemical wastes can be handled satisfactorily when precautions are taken to assure that all containers and transfer equipment are sealed air- and liquid-tight to prevent the escape of vapors. Filler caps on containers should be gasketed to prevent venting to the atmosphere. Each disposal crew member directly involved in filling operations should be issued a self-contained breathing apparatus (Item No. 2203) to prevent injuries resulting from inhalation of toxic vapors (Systems 2, 3, 8, 9, and 11).

Caustic wastes give rise to problems in the transfer and processing operations. Pumps for such service should be constructed of type 316 stainless steel and hoses should be chemically rated, such as the "KEMFLEX" type (Item No. 1101). Vacuum tankers, such as those proposed in System 5 for transport of caustic waste, should also be fabricated from type 316 stainless steel. Barge decks and temporary storage tanks should also be protected by providing corrosion-resistant plastic membrane liners (Item No. 104) when handling caustic materials.

Systems 1, 2 and 3 require a supplementary modification to the existing oil/water separation systems proposed for the processing of spill masses recovered under Scenarios A through D. Gravity-assisted coalescing liquid/liquid separators, similar to the ALLITH Model No. 42-630 (Item No. 1204) are capable of separating any two immiscible liquid phases from emulsion when a sufficient specific gravity differential (>0.05) exists. Additional capital costs for a 1,900ℓ/min unit (500 gal/min) are about $49,000 each.

Systems 7, 8, and 9 require additional modification when handling toxic chemical spill materials. Twelve roll-off sludge containers (Item No. 511) of 19 m^3 capacity each, are proposed for the transport of about 228 m^3 of the anticipated spill mass

TABLE 42. SUMMARY OF RECOMMENDED MODIFICATIONS TO EXISTING SYSTEMS TO IMPROVE APPLICABILITY TO HAZARDOUS CHEMICALS

Scenario	System	Applicability (See Appendix C)	Required Modifications	Capital Cost	Substitution Cost*
E + F	1	S, LTSS, M, LTSM	1-Allith Model 42-630 liquid/liquid separator (1204)	$ 49,000	--
	2	S, VS, TS, TCS, TVS, LTSS, M, CM, VM, VCM, TM, TCM, TVM, TVCM, LTSM	1-Allith Model 42-630 liquid/liquid separator (1204)	49,000	--
			4-Vacuum trucks, type 316, stainless steel (503)	112,000	32,000
			2-Worthington CNGK-84 pumps, Type 316 stainless steel (1016)	12,600	$0.
			1-Goodall KEM-FLEX Hose, 60 meters (1102)	--	$0.
	3	S, VS, TS, TCS, TVS, LTSS, M, CM, VM, VCM, TM, TCM, TVM, TVCM, LTSM	1-Allith Model 42-630 liquid/liquid separator (1204)	49,000	--
			40-Hoover portable waste tanks, type 316 stainless steel (304)	48,000	12,000
			2-Worthington CNGK-84 pumps, type 316 stainless steel (1016)	12,600	
	4	S, LTSS, M, LTSM	1-Allith Model 42-630 liquid/liquid separator (1204)	49,000	--
K + L	5	S, VS, TS, TCS, TVS, LTSS, M, CM, VM, VCM, TM, TCM, TVM, TVCM, LTSM	1-Vacuum truck, Type 316 stainless steel (503)	28,000	8,000
			34-Hoover portable waste tanks with collapsible inner liners (304)	30,600	--
			2-Resistant liners for barge and storage tank (104)	1,080	--
			2-Model 4MF-11 solids pumps, type 316 stainless steel (1019)	8,600	$0.
			1-Model 5MF-15 solids pump, type 316 stainless steel (1019)	13,800	$0.
	6	S, VS, LTSS, M, CM, VM, VCM, LTSM	3-ATL Model 120770-H pillow tanks with ground cloth and cover (201)	28,950	--
			2-Model 4MF-11 solids pumps, type 316 stainless steel (1019)	8,600	$0.
			2-Resistant liners for barge and storage tank (104)	1,080	--

TABLE 42 (continued)

Scenario	System	Applicability (See Appendix C)	Required Modifications	Capital Cost	Substitution Cost*
K + L	7	S, VS, TS, TCS, TVS, LTSS, M, CM, VM, VCM, TM, TCM, TVM, TVCM, LTSM	12-Galbreath 19 m^3 roll-off sludge containers (511)	$60,000	--
			3-ATL Model 120770-H pillow tanks with ground cloth and cover (201)	28,950	--
			1-Model 8MF-15 solids pump, type 316 stainless steel (1019)	13,800	$0.
			2-Resistant liners for storage tank and dump truck (104)	1,080	--
Q + R	8	S, VS, TS, TCS, TVS, LTSS, M, CM, VM, VCM, TM, TCM, TVM, TVCM, LTSM	12-Galbreath 19 m^3 roll-off sludge containers (511)	60,000	--
			2-Worthington CNGK-84 pumps, type 316 stainless steel (1016)	12,600	$0.
			3-Resistant liners for barge, dump truck and stockpile (104)	1,620	--
			1-Allith Model 42-630 liquid/liquid separator (1204)	49,000	--
	9	S, VS, TS, TCS, TVS, LTSS, M, CM, VM, VCM, TM, TCM, TVM, TVCM, LTSM	12-Galbreath 19 m^3 roll-off sludge containers (511)	60,000	42,000
			1-Worthington CNGK-84 pump, type 316 stainless steel (1016)	6,300	$0.
			3-Resistant liners for barge, wash tank and dump truck (104)	1,620	
	10	S, LTSS, M, LTSM	No modifications required.	--	--
	11	S, VS, TS, TCS, TVS, LTSS, M, CM, VM, VCM, TM, TCM, TVM, TVCM, LTSM	1-Worthington CNGK-84 pump, type 316 stainless steel (1016)	6,300	$0.
			3-Resistant liners for barge, wash tank and dump truck (104)	1,620	--
W + X	12	S, VS, TS, TCS, TVS, LTSS, M, CM, VM, VCM, TM, TCM, TVM, TVCM, LTSM	1-Worthington CNGK-84 pump, type 316 stainless steel (1016)	6,300	--
			3-Resistant liners for barge, wash tank and dump truck (104)	1,620	1,080
	13	S, VS, TS, TCS, TVS, LTSS, M, CM, VM, VCM, TM, TCM, TVM, TVCM, LTSM	1-Worthington CNGK-84 pump, type 316 stainless steel (1016)	6,300	--
			3-Resistant liners for barge, wash tank and dump truck (104)	1,620	1,080

Sanitary landfill sites normally accept only municipal solid wastes and other insoluble, inert waste materials. Hazardous wastes may be accepted for disposal if properly pretreated

TABLE 42 (continued)

Scenario	System	Applicability (See Appendix C)	Required Modifications	Capital Cost	Substitution Cost*
	OS-1	S,VS,TS,TCS, TVS, LTSS	5-ATL Model 120770-H pillow tanks with ground cloth and cover (201)	48,250	--
			3-Waukesha Model 3001 "I" pumps, type 316 stainless steel (1015)	30,300	$0.
			3-Worthington CNGK-84 pumps, type 36 stainless steel (1016)	18,900	$0.
			1-Resistant liner for temporary storage tank (104)	540	--
			1-Allith Model 42-630 liquid/liquid separator (1204)	49,000	--
	OS-2	S, VS, TS, TCS, TVS, LTSS, M, CM, VM, VCM, TM, TCM, TVM, TVCM, LTSM	8-ATL Model 120770-H pillow tanks with ground cloth and cover (201)	77,200	--
			3-Waukesha model 3001 "I" pumps, type 316 stainless steel (1015)	30,300	$0.
			3-Worthington CNGK-84 pumps, type 316 stainless steel (1016)	18,900	$0.
			2-Resistant liners for storage and mixing tanks (104)	1,080	--
			1-Allith Model 42-630 liquid/liquid separator (1204)	49,000	--
	OS-3	S, VS, LTSS, M, CM, VM, VCM, LTSM	2-ATL Model 120770-H pillow tanks with ground cloth and cover (201)	19,300	--
			3-Waukesha Model 3001 "I" pumps, type 316 stainless steel (1015)	30,300	$0.
			4-Worthington CNGK-84 pumps, type 316 stainless steel (1016)	25,200	$0.
			1-Allith Model 42-630 liquid/liquid separator (1204)	49,000	--
	OS-4	S, LTSS, M, CM, LTSM	2-Waukesha Model 3001 "I" pumps, type 316 stainless steel (1015)	20,200	$0.
			2-Worthington CNGK-84 pumps, type 316 stainless steel (1016)	12,600	$0.
			2-Resistant liners for storage and mixing tanks	1,080	--

*The cost of replacing a similar equipment item in the basic system with a special equipment component specially suited to hazardous chemical applications, but also suitable for oils and floating chemical applicacions. A substitution cost of $0. indicates that no significant cost difference exists between basic and special equipment items.

to the land disposal of hazardous wastes, although suitable sites may be remotely located from the scene of many hazardous

per transfer to off-site facilities. Each is equipped with a gasketed top opening with suitable tie-down arrangements to maintain the top cover vapor-tight.

On-site processing systems OS-1, OS-2 and OS-3 require modification to the extent of liquid/liquid separators, similar to the ALLITH Model 42-630 proposed for hazardous chemical applications in Systems 1, 2 and 3. Toxic and volatile wastes processed in these on-site systems also require flexible pillow tanks for temporary storage, cited as a modification to System 6 previously.

SCENARIO E - HAZARDOUS CHEMICAL ONLY, NO DEBRIS, CALM WEATHER, WARM AIR TEMPERATURE - SYSTEM 14 - FOR GASEOUS CHEMICALS

> Scenario E is defined as: Hazardous chemicals (liquid, solid, or gaseous) dispersed in water, no solid debris, warm air temperature.
>
> Gases may be liberated from either the thermo-chemical reaction of liquids (or solids) with water or mixture of a low boiling point liquid with water.

While mixture of these gases with air is possible, it is less likely where higher density vapors result. Mixture with water sprays (aerosols) or water vapor is also possible. The total volume of the gas spill is assumed to be approximately 76 m^3 (2,700 cu ft) based on a gas/air mixture ratio of 1:1.

System 14

System 14 is defined as follows (Figure 30):

> Transfer of recovered gaseous products from PRV is by fan or blower and flexible ducting mounted on the workboat. Gaseous products are passed into a towable pillow storage bag (Dracone) for transfer to shore. Gases are transferred at shore to on-site flaring devices for disposal, or are transferred to tank trucks for transport to off-site treatment and dipsosal facilities.

Critical equipment elements of the system are shown in Table 43. The total system life cycle cost for an estimated 20-yr life span is \$770,163 and the system's annual cost is \$24,150.

An estimated transfer time of 8 min is considered reasonable for this system, based on the blower flow-rate of 9.91 m^3/min (350 cfm) and the combined flaring device burn rate of 10 m^3/min.

Chemicals Which Can and Cannot Be Handled--
All recoverable gases can be handled by System 14 for transfer to shore-side disposal or transport equipment.

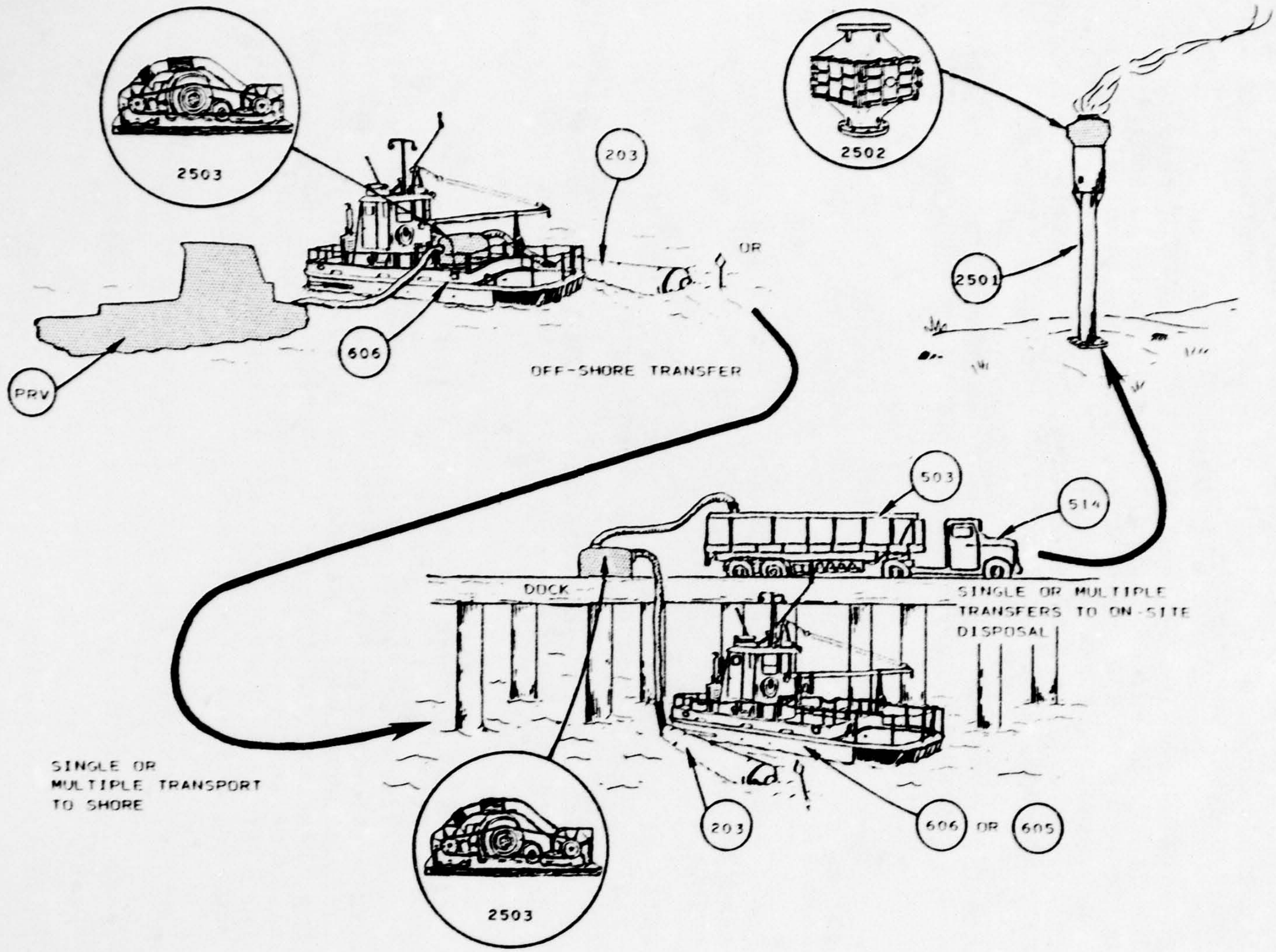

FIGURE 30. SYSTEM 14, SCENARIO E.

TABLE 43. SYSTEM 14: CRITICAL EQUIPMENT ELEMENTS

Quantity	Equipment Element	Item No.*	Estimated Life (Yr)	Capital Cost (1978 $)	Approximate Annual O&M Costs ($)	Estimated Salvage Value ($)
1	Workboat	606	20	80,000	5,600	4,000
1	Towable pillow tank	203	5	49,000	3,150	--
10	Flaring devices	19xx	10	20,000 (2,000)†	1,000	1,000
10	Flame arrestors	--	10	4,000 (400)†	200	200
1	Blower unit	10xx	10	2,500	200	250
4	Tank trailer	512	10	80,000 (20,000)†	8,000	4,000
1	Truck-tractor	514	10	59,000	6,000	4,000
	Contingency (10%)	-	-	29,050		
	Life cycle cost =	$819,163				
	Total annual cost	24,150				

*See Appendix E
†Unit costs

Highly toxic gaseous products should not be disposed of on-site by flaring devices, due to the noxious vapors generated by the process. These gases should be transported directly to off-site facilities where they can be recovered and purified for reuse, or disposed of in an environmentally acceptable manner. Highly volatile gaseous products can be handled using System 14 when in-line flame arrestors are provided to prevent flashback along flaring device inlet lines.

Disposal by flaring devices is not applicable to nonflammable gases, which must be transported directly to off-site treatment or disposal facilities.

Approximate Quantity of Spill Mass Which Can Be Handled--

The transfer rate of System 14 is limited by the flow rate of the gas transfer blower and by the capacity of the towable storage bag. One blower transfer unit is provided with a volumetric flow rate of 9.91 m^3/min (350 cfm). Thus, the entire anticipated gaseous spill mass of 76 m^3 could be transferred in about 8 min with the blower operating continuously. One towable storage bag is capable of holding up to 490 m^3 of gaseous product, more than adequate for the expected spill volume. Only one transfer to shore by pillow bag will be required for the expected spill volume of 76 m^3.

Ten flaring devices are recommended to provide destruction at a rate of 10 m^3/min. Disposal of the entire gaseous spill mass of 76 m^3 is expected to require substantially less than 1 hr.

Feasibility of Development Including Critical Elements--

All equipment components included in System 14 are available on the commercial market. Development of the equipment into a mobile Coast Guard response system would require little engineering expense other than proper sizing and acquisition of components.

Environmental Impacts of System Operations--

Potentials for environmental impact in the disposal system include the following:

- Incomplete combustion of gases by flaring device
- Leakage of gaseous product from pillow storage bag
- Leakage of gaseous products at connection points between blower, ducting, storage bags, flaring devices or transport vehicles.

Approximate Size and Weight of Equipment--

Table 44 shows the approximate dimensions and weights of each equipment element for System 14. Plans for each element are shown in the indicated figures.

TABLE 44. SYSTEM 14: DIMENSIONS AND WEIGHTS OF CRITICAL EQUIPMENT ELEMENTS

Equipment Element	Item No.	L (m)	W (m)	H (m)	D (m)	Weight (Kg)	Figure*
Workboat	606	11.73	5.03	1.60	-	31,750	D-15
Pillow tank (towable - in envelope)	203	3.0	2.0	2.0	-	743	D-1
Flaring devices	19xx	Cylindrical	Cylindrical	2.44	.41	136	--
Blower unit (includes ducting)	10xx	.71	.51	.34	-	54	--
Flame arrestors	--	.43	.37	.37	-	25	--
Tank trailer	512	9.80	--	3.35	1.68	7,484	D-8
Truck-tractor	514	5.98	2.44	2.98	--	19,800	D-10

*For conceptual drawing, see figure indicated, Appendix E.

Transportability by Existing Coast Guard Vessels and Aircraft Capability--

Appendix F gives the dimensions of various cargo holds for Coast Guard aircraft and vessels.

Transportability by Other Than Coast Guard Vessel and Aircraft--

See Appendix F.

Special Requirements--

Limiting elements of System 14 are the portable flaring devices, which cannot be transported by air or sea. These items are transportable to the spill site by road vehicles only.

Specially trained Coast Guard personnel are required for installation and operation of all equipment included in System 14. During simultaneous operation of all equipment elements, it is estimated that a maximum of eight persons are required as crew (includes workboat-1, blowers-2, pillow tank-1, tank truck-1, and flaring devices-3).

Diesel fuel must be provided for the operation of the blower (Item No. 10xx) and the workboat (Item No. 606).

CONCEPTUAL DISPOSAL EQUIPMENT FOR HAZARDOUS CHEMICALS

The ability of existing portable equipment systems to treat and dispose of hazardous chemical spills on-site is somewhat limited in terms of chemical applicability and operational environment, as demonstrated in the previous section. Limitations of present spill disposal equipment are in part due to the fact that in many cases, disposal equipment is not specifically designed to accommodate the highly toxic, caustic, or volatile characteristics of hazardous spill materials. Most state-of-the-art spill disposal equipment is primarily intended for oils and oily wastes, but has some limited application to hazardous materials disposal. Much of the recent research effort in spill prevention and countermeasures has concentrated on hazardous waste disposal, and the state of the art is expected to advance rapidly.

The limitations of existing spill disposal equipment for handling hazardous chemicals and contaminated debris are:

- Lack of safe, environmentally acceptable on-site disposal methods for highly hazardous materials
- Lack of adequate vapor containment techniques when transferring, storing, and treating materials emitting hazardous vapors
- Lack of effective, low-temperature washing techniques for debris contaminated with hazardous chemicals.

Several conceptualized equipment components and treatment/disposal techniques are discussed in this section and further research and development is recommended. Each conceptual equipment component or treatment/disposal method is proposed in response to a specific limitation with respect to the chemical applicability to, or operational environment of, an existing disposal system.

Road-Portable Hazardous Wastes Incinerator

An example of this concept is the MB Associates/EPA Mobile Environmental Restoration Incinerator Complex (ERIC) (Figure 31). A solid/liquid/sludge waste incinerator, afterburner and stack gas processing system, mounted on heavy-duty highway trailers, enables over-road transport to spill sites by truck-tractor. The incinerator incorporates a rotary kiln combining controlled atmosphere and excess air inlet capabilities. High kiln temperatures (to 980°C) and extended residence times (to 1 hr) assure complete degradation and/or disposal of hazardous materials. A high-temperature (1,090°C) excess air afterburner section with extended dwell times (>2 sec) insures destruction of pesticide wastes in compliance with Federal Air Quality Regulations. Particle scrubbing is utilized to remove fly ash and small particulates from the exhaust gas stream. An absorber scrubber is used for removal of SO_2 and HCl. The mobile incineration unit is equipped with a self-contained generator set for remote operations.

The mobile hazardous waste incinerator is particularly applicable to on-site, shore-side treatment and/or disposal of toxic liquid effluents, as described under System OS-3. On-site incineration would also be useful for the detoxification of hazardous sludges and small solids, as in Scenarios K and Q.

The example incinerator is presently being developed under contract to the U.S. EPA, Edison, New Jersey. The system has yet to be field-demonstrated, but appears to have potential for many types of applications.

Concept: Sea-Going Hazardous Waste Incinerator

The M/T Vulcanus, owned by Ocean Combustion Services, B.V., The Netherlands is an example of a process which can be employed at major marine spill cleanups. Similar in concept to the unit described above, this system, installed on a converted cargo ship or equivalent vessel, can be brought directly to the spill site for disposal operations. Again, as above, a high temperature excess-air afterburner is utilized with extended dwell times to destroy toxic wastes in order to comply with air standards. Particle and absorption scrubbing are used to remove particulate and HCl/SO_2 emissions from the exhaust gas stream. The incinerator kiln can function either as a rotary kiln or fluidized-bed incinerator with high temperature and extended residence time

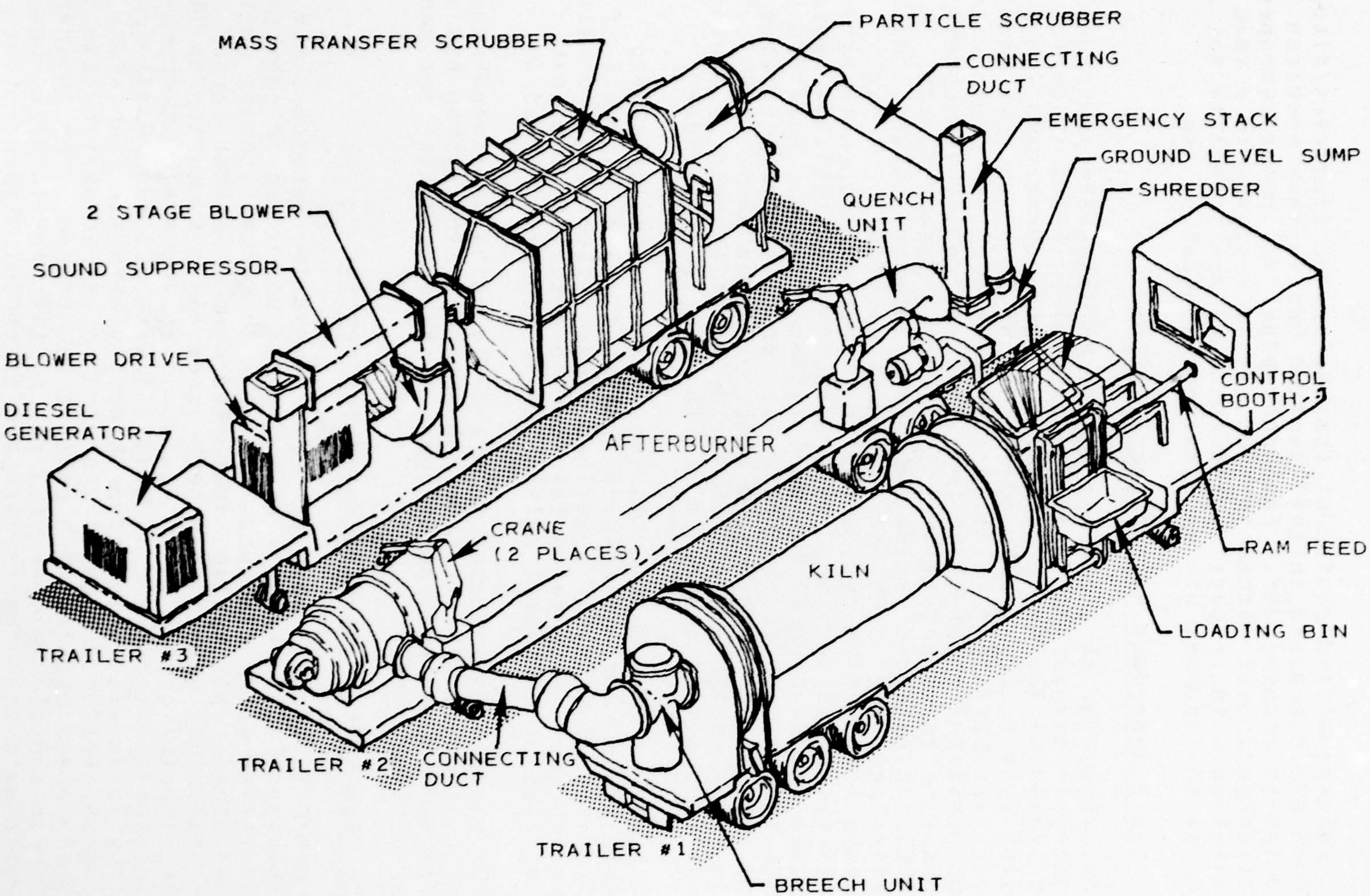

FIGURE 31. MOBILE ENVIRONMENTAL RESTORATION INCINERATOR COMPLEX

capabilities for complete destruction of solid wastes. The incinerator is capable of accepting ram-fed solids, or liquids and sludges injected at the kiln floor. The vessel is equipped with both liquid and bulk solids handling capabilities for spill mass transfer from the primary recovery vessel. On-board storage is provided for up to 3,800 m^3 of recovered spill chemicals and debris.

The sea-going hazardous waste incineration vessel is specifically applicable to the on-site treatment and/or disposal of hazardous chemical spills, as described under System 1. Ocean disposal is also applicable to disposal of spill masses containing debris, when some form of on-board volume reduction is included.

The ocean incineration technique has been demonstrated by the example incineration vessel, in a burn of approximately 16,000 metric tons of organochlorine wastes by the Shell Chemical Company of Houston. No adverse environmental impacts were observed, and it is estimated that up to 90 percent of the liquid wastes were completely oxidized. This concept has the disadvantage of relatively slow response times, and the need for several such vessels widely dispersed to respond to the many spill events. Also, the incineration of certain wastes having highly-corrosive combustion products can damage the stack and scrubbing equipment. Incineration oil or chemicals which are only moderately hazardous and amenable to other disposal options is probably not cost-effective.

<u>Concept: Low-Temperature Debris Washing Technique</u>

The use of ultra-low ($<<0^{o}C$) freezing point solvents or wash water additives to enable debris washing at below freezing ambient temperatures might prove useful in colder climates. Where chemically compatible, a low-cost water additive such as automotive antifreeze fluid would prevent ice formation, and allow the removal of hazardous materials from debris.

Another option is the use of a high-velocity air jet to remove both liquid and solid chemicals from debris. The air-jet system would consist of a portable high-pressure compressor and motor, and a flexible pressure hose with a trainable nozzle to provide a high-velocity air stream.

These low-temperature washing techniques are specifically applicable to the low ambient temperature washing of large, contaminated solid debris (Systems 12 and 13, Scenario X). High velocity air "washing" techniques may not be suitable for smaller contaminated debris (Scenarios Q, R).

Both concept options utilize commercially available components and solvents, and can readily be developed into working systems. Since no recycling of wash fluids is included in Option 1, solvents

or water additives used must be relatively inexpensive. Wash fluids may be chemically incompatible with the hazardous spill material. The air-washing system appears to be a viable technique for cleaning hazardous materials from the surface of large solid debris, particularly metal items.

Bulk Hazardous Solids Transport Container

A road-portable container vehicle is required for safely transporting hazardous contaminated solid spill debris to off-site facilities in a fully-contained manner. The container is mounted on a heavy-duty commercial highway trailer chassis (Figure 32), and can be hauled by truck-tractor on most roadways with adequate load-bearing capacity. Debris are loaded into the container through a hydraulically-actuated, top-opening door, gasketed for vapor containment. Rear-opening, gasketed doors allow unloading of debris by hydraulic ram, a technique also applicable to load distribution. Total volumetric capacity of the solids container vehicle is approximately 57 m^3 (2,000 cu ft) with load-carrying capacity in excess of 19 metric tons. An auxiliary engine is included to provide hydraulic power for unloading ram and top-door actuation. The trailer interior and exterior are epoxy-coated to increase corrosion-resistance.

The bulk hazardous solids transport container is directly applicable to transfer of large size contaminated debris where washing is impractical or where toxic or volatile substances remain after washing (Systems 12 and 13). Solid debris volume need only be reduced to a size that will pass through the top-opening door (2.4 m W x 2.7 m L). The container is useful for temporary on-site storage and/or transport of nonpumpable spill debris which contain toxic or volatile vapors.

The concentrated hazardous solids container is very similar in design to commercially available refuse transfer trailers which are commonly used in solid waste management. Relatively simple modifications to the standard transfer trailer are required to provide a vapor-tight seal on loading and unloading doors. These units appear to be readily adaptable to the hauling of debris contaminated by hazardous chemicals.

Oil/Water Vapor Seal for Hazardous Material Transport

A simplified vapor containment technique is recommended for transport of debris contaminated with hazardous toxic or volatile materials. Vapors generated by the debris are contained by a combination water bath and oil barrier. Debris are placed in an open-top roll-off container, specially sealed to contain liquids without leakage (Figure 33). Debris are submerged by a water bath of sufficient depth to fully cover all debris by at least 0.3 m (1-ft). An oil layer of approximately 0.1 (4-in) depth is poured on top of the water bath to float and create an

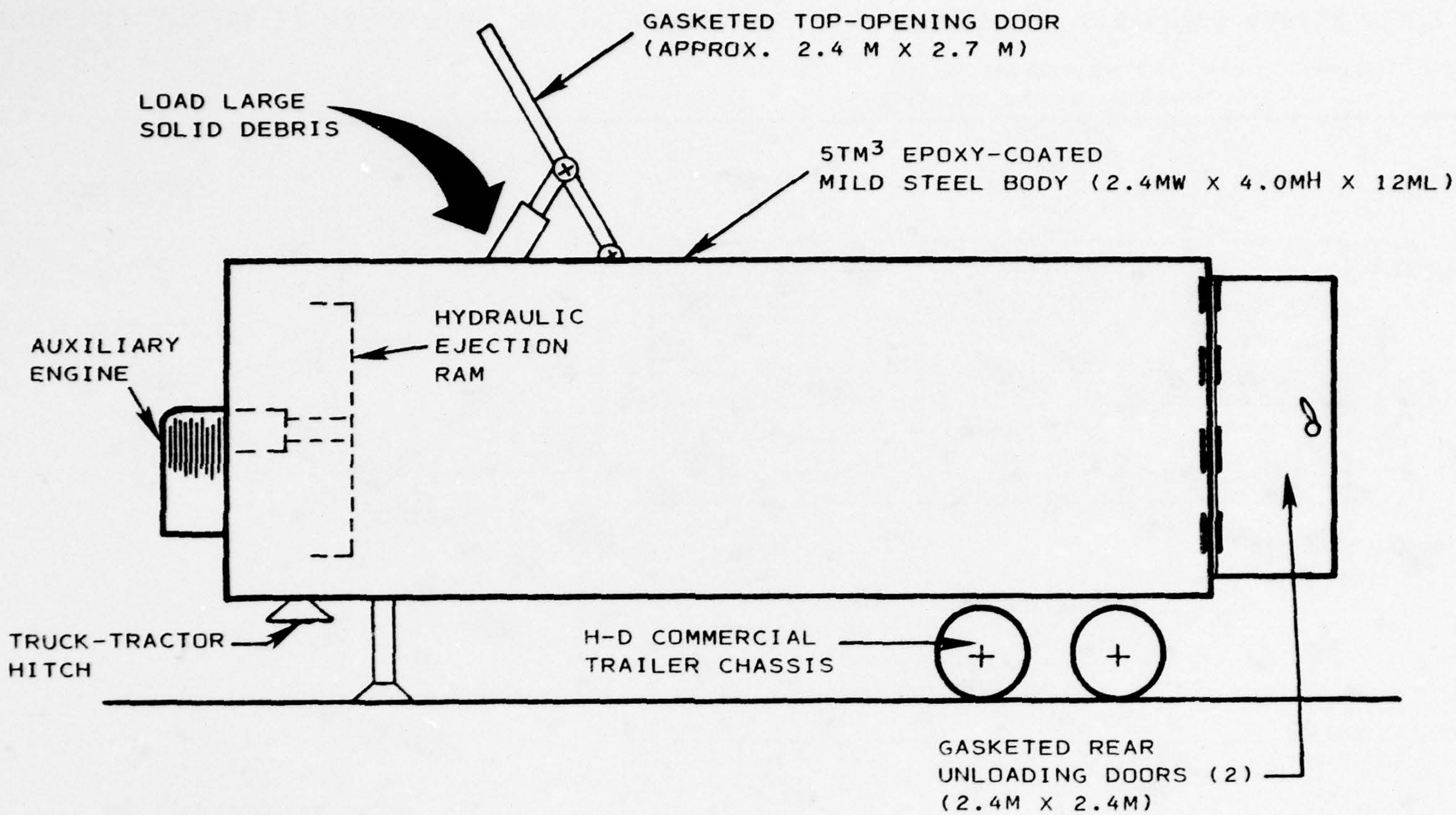

FIGURE 32. BULK HAZARDOUS SOLIDS TRANSPORT CONTAINER

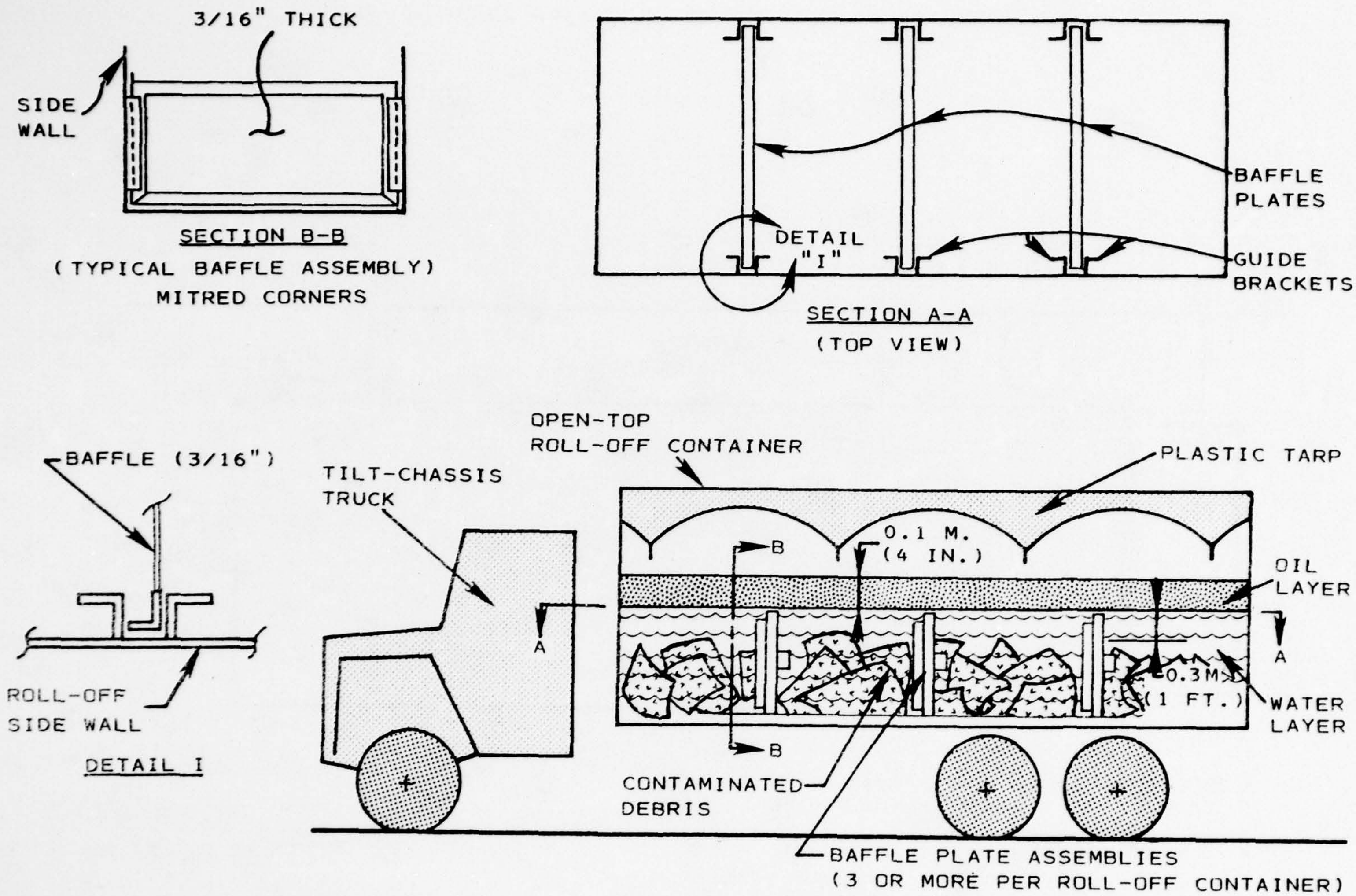

FIGURE 33. OIL/WATER VAPOR SEAL FOR HAZARDOUS MATERIAL TRANSPORT (INCLUDES BAFFLE PLATE ARRANGEMENT TO PREVENT LIQUID SURGE DURING BRAKING/ACCELERATION)

effective vapor seal. Highly viscous nontoxic oils, such as No. 4-6 fuel oil, should be used for the most effective seal. Water and oil used for vapor containment are disposed along with the contaminated debris at off-site disposal facilities. A plastic tarp or cover is tied down over the open container to control splashing and loss of oil and water. "Surge" of the upper surface of the water and oil film mass, during braking of the vehicle, can be markedly reduced by "compartmentalizing" the interior of the roll-offs. This is done by means of three or more baffle plate assemblies. Each is fabricated from steel plate (3/16 in minimum), framed by angles (e.g., 3-in x 1/4 in) with mitred corners. Each of the plate assemblies is maintained in a vertical attitude by two groups of angles welded to the sidewalls of the roll-off (Detail I). The height of the top edge of the plates above the roll-off floor should be approximately equal to the level of the water/oil interface.

This simplified vapor containment technique is useful in transporting medium to large sized hazardous debris (Scenarios Q and W) to off-site disposal facilities. The technique provides a quick-response transport method for hazardous material solids using readily available equipment and supplies.

This technique appears to be suitable for substances which have low vapor pressures, or vapors which are soluble in water. High vapor pressure substances will not be effectively contained, as hazardous vapors will simply bubble up through water and oil barriers. The technique is obviously not applicable to substances which are reactive with water. Water/oil barriers, however, can be readily implemented when specific vapor-containment techniques or equipment are not available.

Field-Sealable Debris Bags

In this conceptual process, large solid spill debris contaminated with hazardous or toxic materials are wrapped in flexible pond liner sheeting and sealed into a vapor-tight "bag". A dump truck bed is filled with sand to form a cushion to prevent punctures, and a sheet of plastic liner material laid into the bed. Debris is placed in the bed onto the approximate center of the liner, and the edges of the liner folded up and joined by means of an on-site thermal seam welder (Figure 34). Ends of the liner are folded and seamed to complete the sealed debris bag.

The debris bag technique is directly applicable to the safe, contained transport of large solid debris contaminated with hazardous materials (Systems 12 and 13). "Bagging" of hazardous debris solids is especially useful when low ambient temperatures or other considerations preclude the washing of toxic or volatile substances from debris. The technique may also be applicable to the safe stockpiling of debris which generate hazardous vapors.

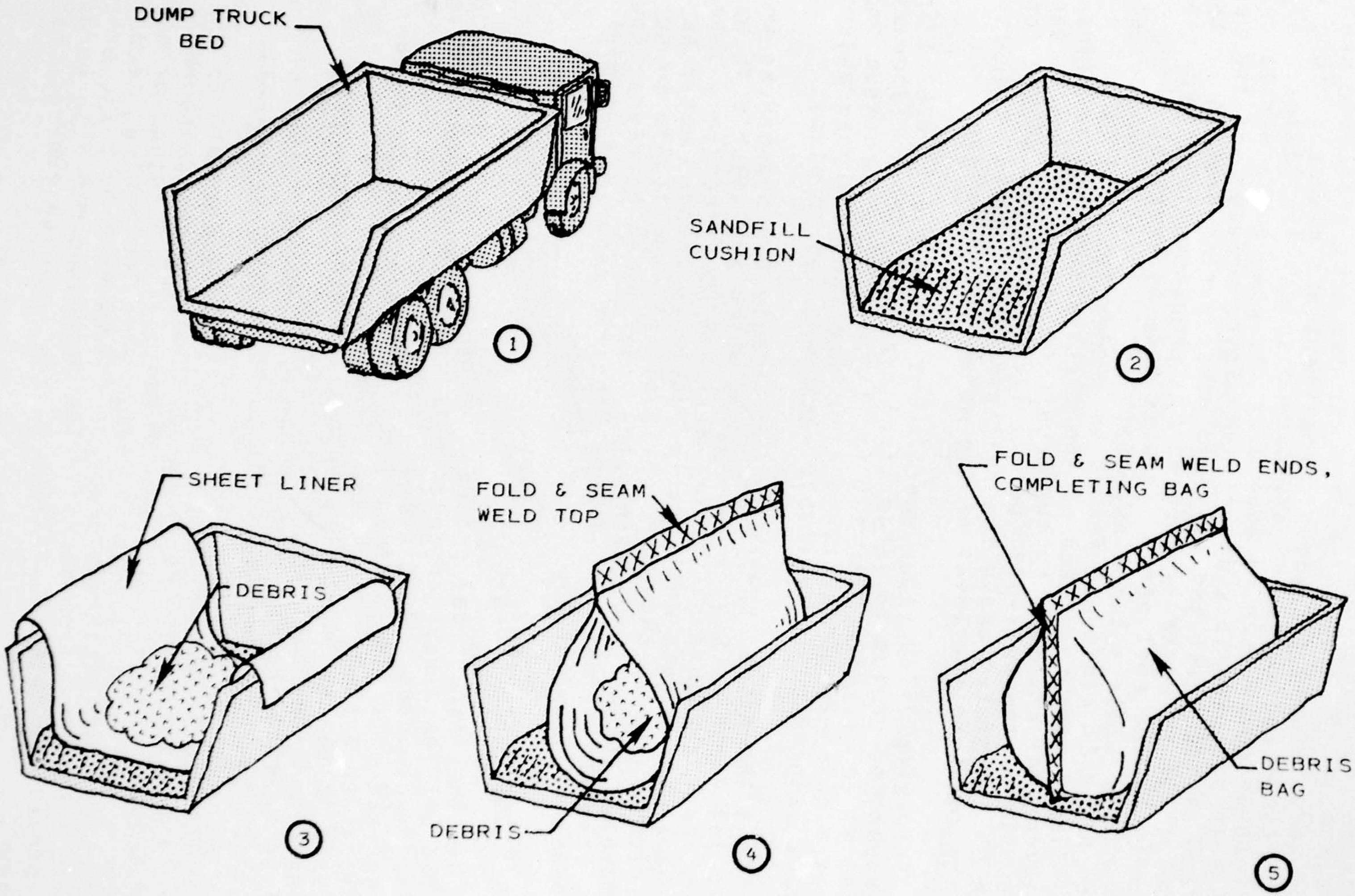

FIGURE 34. FIELD-SEALABLE DEBRIS BAGS

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DISPOSAL SYSTEMS AND TECHNIQUES FOR OIL AND HAZARDOUS CHEMICALS--ETC(U)

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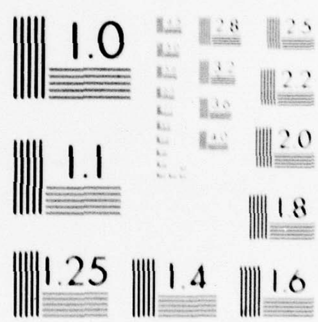


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Since all components of this conceptualized transport/storage system are commercially available, such a working system can be readily developed. The major questions concerning the viability of this technique, is the puncture resistance of the liner material when handling jagged, sharp metallic or organic solids. The use of a cushioning sand bed and careful loading of debris onto liner should minimize the possibility of liner puncture and consequent vapor leakage.

Nonsparking, Corrosion-Resistant Crane and Loader Buckets

Previous project findings have indicated the need for crane or loader buckets or blades fabricated from corrosion-resistant, nonsparking, nonmetallic materials to allow safe handling of toxic, flammable, or caustic solids. Glass-reinforced plastics (GRP) or other materials fabricated into required bucket configurations provide adequate strength and similar operation to their metallic counterparts. Replaceable wear surfaces, to protect areas exposed to abrasion, increase the service life of the bucket or blade.

Special loader and crane buckets are particularly applicable to on-shore collection and transfer of volatile contaminated solids, such as soils and sands (System 7). The use of nonsparking bucket materials are useful under conditions of high wear and corrosion rates, a common characteristic of caustic materials handling.

Glass-reinforced plastics are readily available and moldable into any conceivable shape. GRP can be reinforced in areas of high stress or wear by adding additional layers of fiberglass matting and resin to the lay-up.

Portable Vapor Containment System

A portable system should be developed for the containment and treatment of hazardous chemical vapors during filling operations involving volatile or toxic fluids. The system utilizes a two-phase filler nozzle (vapor closure) to allow filling of tanks simultaneously with vapor displacement and collection (Figure 35). Displaced vapors are passed to activated carbon adsorption colums for vapor removal from the displaced air stream. Spent carbon granules are collected in a storage container for subsequent disposal or thermal regeneration. Residual gases exiting the carbon sorption columns are stored in tank trucks for transport off-site, or if sufficiently clean, are released directly to the atmosphere. Carbon sorption columns and spent carbon storage bins are mounted on a heavy-duty commercial highway trailer chassis for transport by truck-tractor. The handheld vapor closure unit is connected to the trailer by flexible ducting, and includes a standard coupling for the waste fluids input hose.

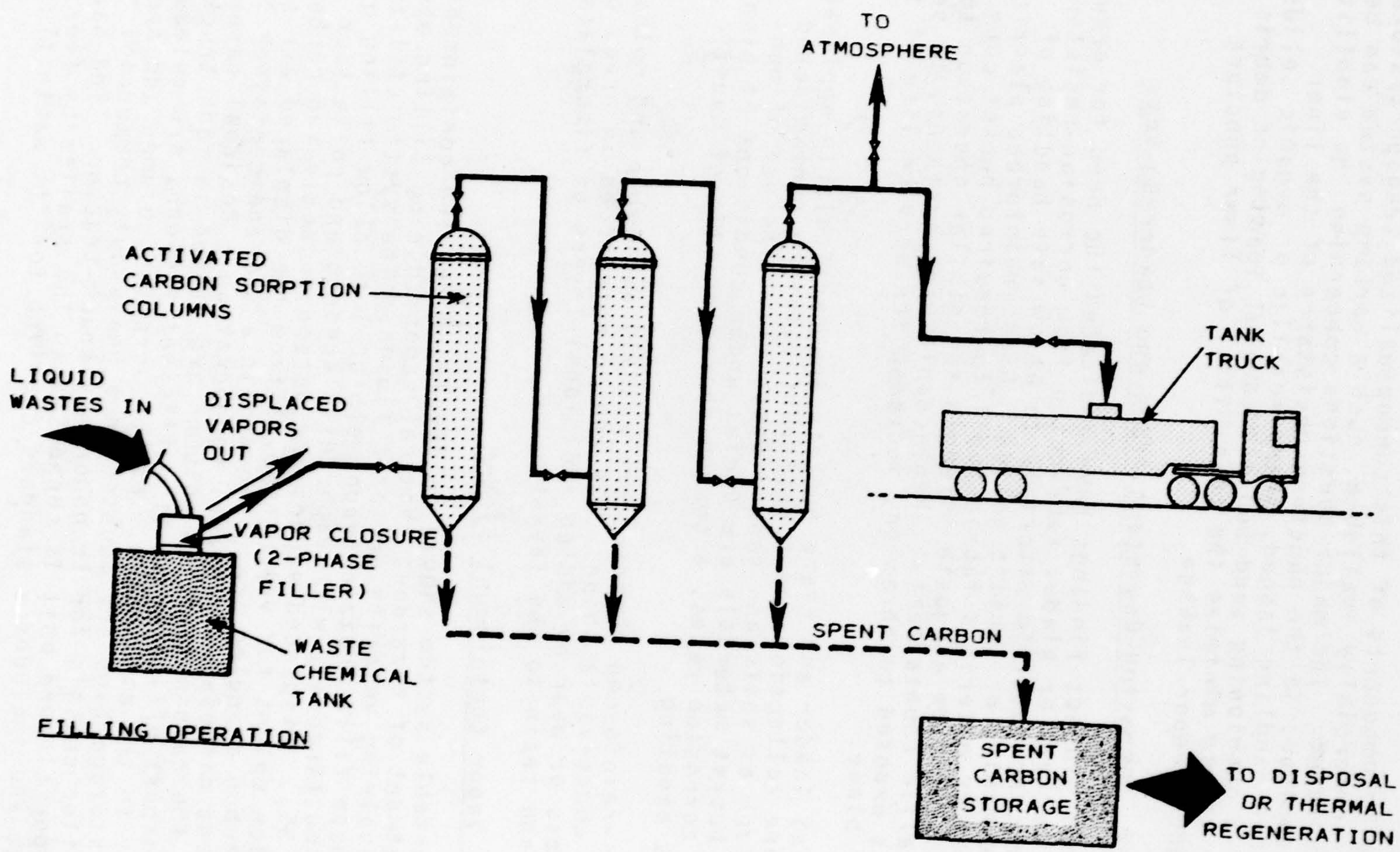


FIGURE 35. PORTABLE VAPOR CONSTAINMENT SYSTEM

The portable vapor containment system is applicable to all hazardous waste disposal systems in which a hazardous fluid is pumped into a tank of some kind, displacing air and toxic or volatile vapors (Systems 1-4 and 5-7).

Vapor containment at petroleum or other hydrocarbon loading racks is a well-established technology. It is conceivable that a trailer-portable version of these systems could be designed for on-site use. All equipment would have to be custom-engineered, as no commercial portable vapor containment equipment currently exists.

VI. SUMMARY

The U.S. Coast Guard has determined that systematic techniques and equipment are required to improve the efficiency and effectiveness of oil spill cleanup debris disposal practices. The Coast Guard also recognizes that chemicals and contaminated debris collected during cleanup of hazardous material spills must be disposed of properly. Accordingly, the Coast Guard has examined existing and potential methods and equipment for dealing with these materials. This report is a result of that study.

During early phases of this study, 24 scenarios were identified which describe combinations of environmental and spill mass characteristics that may be encountered in oil and hazardous chemical spill debris disposal activities. Using these predesignated scenarios as a starting point, general disposal methodologies were developed based on literature and personal descriptions of past disposal experiences. Thirteen disposal equipment systems (plus four auxiliary systems) were then described to illustrate the identified disposal methodologies (Table 45).

OILS AND FLOATING CHEMICALS

It was found that for spill masses including oils, some systems are applicable for both warm and cold weather, while others are useful only in warmer conditions. The same systems were also found to be directly applicable to floating chemicals, although some limitations are observed where toxic or volatile chemicals are involved. Yet, all possible scenarios have at least one system which can be used under the described spill mass and climatic conditions.

Subsequent work was conducted to select the disposal systems best suited to Coast Guard needs for both oils and chemical spills. The best systems were selected according to specific performance and cost criteria.

It was observed that the 13 transport/disposal equipment systems do not each represent the same degree of ultimate material disposal. In all cases except System 1, it is necessary to combine the debris-handling systems with various on-site (OS-1, 3, and 4) and contractor-operated, off-site disposal facilities (CF), to provide a complete disposal system. These

TABLE 45. SUMMARY OF DISPOSAL EQUIPMENT SYSTEMS

Scenario	System	Description (Key Elements)	Total Estimated Life Cycle Cost (1978 $000)	Oil Groups*	Spill-Mass Volume Handled (Capacity)
A or B	1	Off-shore-oil/water separation/incineration	876	II, III	262 m^3 (in 2 days)
	2	Oil/water separation/vacuum trucks	1,058	I, II, III, IV, V	303 m^3 per transfer
	3	Oil/water separation Portable storage Crane/forklift Flatbed truck	975	I, II, III, IV, V	152 m^3 per transfer
	4	Towable pillow tanks Donuts	1,061	I, II, III, IV	490 m^3 per transfer
G or H	5	Storage Trucks	945	I, II, III, IV, V	180 m^3
	6	Storage On-shore liquid/solids separation	1,001	I, II, III, IV, V	180 m^3

Scenario	System	Description (Key Elements)	Total Estimated Life Cycle Cost (1978 $000)	Oil Groups*	Spill-Mass Volume Handled (Capacity m^3)
	7	In-land storage Liquid/solids Separation	619	I, II, III, IV, V	180
M or N	8	Barge - scows Roll-off bins Oil/water separation Portable tanks Trucks	1,534	I, II, III, IV, V	3,800
	9	Barge Storage Roll-off bins Washing equipment Trucks	1,371	I, II, III, IV, V	3,800
	10	Barge Shredder Chipper Storage Roll-off bins Trucks Treatment/disposal	1,718	II, III	3,800
	11	as in System 10 Large whole-tree chipper Washing equipment	1,728	I, II, III, IV, V	3,800

*See Appendix

TABLE 45 (continued)

Scenario	System	Description (Key Elements)	Total Estimated Life Cycle Cost (1978 $000)	Oil Groups*	Spill-Mass Volume Handled (Capacity)
S or T	12	Liner Washing equipment Chipper Truck	1,048	I II III IV V	5 tons (batch)
	13	Liner Cranes Washing equipment Cutting torches Trucks	973	I II III IV V	5 tons (batch)
General	OS-1	Storage Demulsifier Oil/water separation Trucks	631	I II III IV V	380 m^3/day
	OS-2	Storage Oil/water separation Trucks Sludge press Conveyor Package chemical Biological Ultrafiltration plants	1,192	I II III IV V	589 m^3 (batch)
General	OS-3	Storage Oil/water separation Trucks Incineration	1,227	I II III IV V	86 m^3 (batch)
	OS-4	Storage Liquid applicator vacuum truck	241	I II III IV V	292 m^3 (batch)

combined systems can then be compared directly to one another and rated against the same criteria.

It is recommended that these complex systems be developed as individual systems. Accordingly, ten of the systems (including three of the four on-site systems) were recommended for inclusion in eventual development programs:

- System 1
- System 2
- System 4
- System 7
- System 8
- System 9
- System 13
- System OS-1
- System OS-3
- System OS-4

The details of the 10 systems included in the Executive Briefing Packages and Technical Description Packages are condensed into table form for easy reference and to serve as an overview. The following tables are included:

- Summary of Characteristics and Handling Procedures for Solid/Liquid Spill Mass (Table 46)
- Summary of System Configuration, Transportation and Crew Requirements (Table 47)
- Summary of Spill Mass Handling Capabilities and Limitations (Table 48)
- Summary: Development Schedules and Costs (Table 49).

HAZARDOUS CHEMICALS

Special handling for hazardous chemicals procedures can be categorized as follows:

- Sinking chemicals mixed with water or sediments
- Water contaminated by miscible chemicals
- Volatile chemicals
- Toxic chemicals
- Caustic chemicals
- Gaseous chemicals.

General treatment and disposal procedures include phase separation (e.g., filtration), incineration, chemical and biological treatment, land disposal, and miscellaneous techniques.

TABLE 46. SUMMARY OF CHARACTERISTICS AND HANDLING PROCEDURES FOR LIQUID/SOLID SPILL MASS

SYSTEM	SCENARIOS(S)	SPILL MASS CHARACTERISTICS	STEPS IN PROCESS
1	A,B,C&D	Oils or oils and floating chemicals dispersed in seawater (no solids present) recovered off-shore	• Pump spill mass into workboat • Separate product (optional demulsification) • Pump aqueous effluent overboard • Store and incinerate concentrated product
2			• Pump spill mass into workboat • Separate product (optional demulsification) • Pump aqueous effluent overboard • Pump product into vacuum tank trucks on barge - tow to shore
4			• Pump spill mass into workboat • Separate product (optional demulsification) • Pump aqueous effluent overboard • Pump product into pillow tanks or donuts - tow to shore
7	G,H,I&J	Oils or oils and floating chemicals mixed with soil, sand, or other inorganic sorbents. Spill mass has variable fluidity: • Low fluidity=high solids • High fluidity=low solids (slurry)	• Collect spill mass by backhoe into compact pick-up zone • If spill mass has low fluidity: - Load dump truck by crane, or - Pump via tubular conveyor • If spill mass has high fluidity: - Store, transport to off-site, or - Pass through solids/liquid separator: liquid to tank truck, transport to off-site disposal
8	M,N,O&P	Oils or oils and floating chemicals, dispersed in water, and large quantities of solid organic debris: seaweed, sorbents, misc. storm debris - (solid:liquid ratios as high as 100:1	• Place spill mass into either: - Open-top roll-offs with drainage screens on deck of workboat - Barge with liner, towed by workboat - Small liftable skows, towed by workboat • Separate product - transfer to portable tanks on workboat (optional) • Pump aqueous effluent overboard • Transfer to shore: - Bins or skows to flat-bed trailer - Solids on barge to dump truck • Transport liquids to on-site factory • Transport solids to off-site factory.

TABLE 46 (continued)

SYSTEM	SCENARIO(S)	SPILL MASS CHARACTERISTICS	STEPS IN PROCESS
9	M,N,O&P	Oils or oils and floating chemicals, dispersed in water, and large quantities of solid organic debris: seaweed, sorbents, misc. storm debris - (solid:liquid ratios as high as 100:1).	• Place spill mass onto barge - towed ashore by workboat • Unload at dock by crane into temporary storage tanks (site-erectable) • Wash, screen and drain on shore • Transport liquids in bins to on-site process on flat-bed trailers. • Transport solids in bins or in dump-truck to off-site disposal facility.
13	S,T,U&V	Oils or oils and floating chemicals, dispersed in seawater, soaking large solid debris: logging waste, metallic fragments (pieces of ship's hull, oil drums), plastic fragments.	• Place recovered solids onto deck of PRV, workboat or barge by crane with grapple • Tow barge to shore by workboat • Off-load solids by crane into lined tank • Wash solids with solvents, detergents • Transfer liquid effluent to on-site treatment or disposal (OS) • Compact metal debris after use of cutting torch • Transport debris to CF, for salvage or disposal
OS-1	ALL	Potential residues containing oil or oil and floating chemicals separated from or dispersed in aqueous effluent or slurries. Received from Systems 2, 4, 7, 8, 9, 13, and sometimes System 1.	• Pump influent to any/all of: - Temporary site-erected storage tank - Tank with demulsifier agent - Hydrocarbon/water separator • Monitor separator effluent • Discharge aqueous effluent from separator to watercourse (if standards met) • Pump concentrated product to temporary storage tanks • Transfer concentrated fluid to vacuum tank truck • Transport for treatment/disposal at CF
OS-3	ALL		• Pump influent to any/all of: - Temporary site-erected storage tank - Tank with demulsifier agent - Hydrocarbon/water separator • Monitor separator effluent • Discharge aqueous effluent from separator to watercourse (if standards met) • Burn concentrated fluids in incinerator.

TABLE 46 (continued)

SYSTEM	SCENARIOS(S)	SPILL MASS CHARACTERISTICS	STEPS IN PROCESS
OS-4	ALL	Potential residues containing oil or oil and floating chemicals separated from or dispersed in aqueous effluent or slurries. Received from Systems 2, 4, 7, 8, 9, 13, and sometimes System 1.	• Pump incoming fluids into temporary site-erectable storage tank • Dispose of aqueous and/or concentrated waste by either: - Transportation by tank truck to OS burial (using earth-moving equipment) or - Transferring to cultivator (liquid applicator vacuum tank truck)

TABLE 47. SUMMARY OF SYSTEM CONFIGURATION, TRANSPORTATION, AND CREW REQUIREMENTS

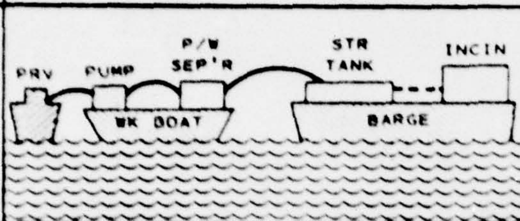
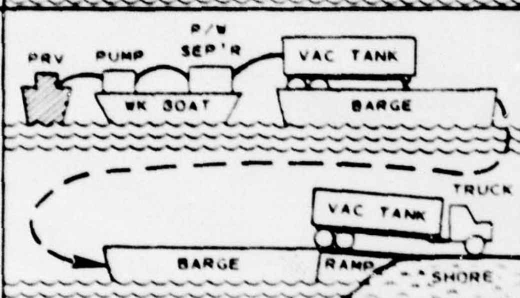
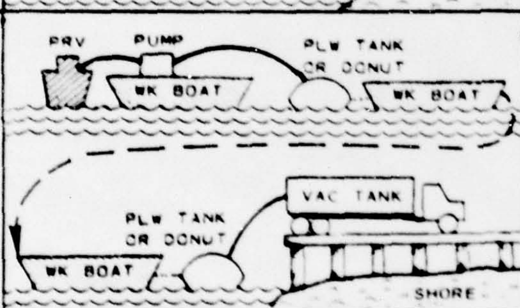
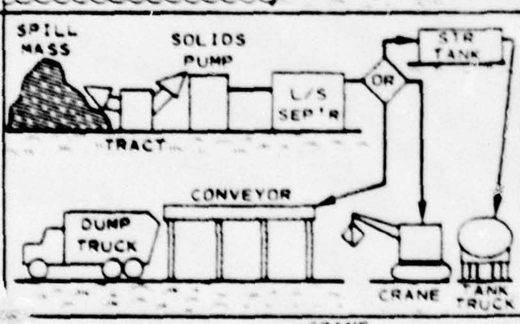
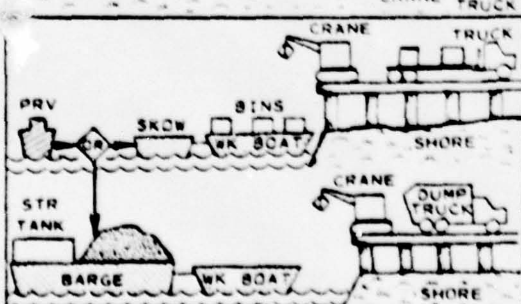
SYS-TEM	Schematic Diagram	OPTG. PERS.	Compatibility w/USCG Equip Transportation	Operation
1		6	All but Incinerator by C-130 A/C	Barge 2 Work Boat 1 Pump 1 P/W Separator 1 Incinerator 1
2		5	All but vacuum-tank trailer(s) by C-130 A/C	Barge 2 Work Boat 1 Pump 1 P/W Separator 1
4		10	All but vacuum-tank trailer(s) by C-130 A/C	Work Boat 2 Pillow Tanks 1 Donut 1 Pump 1
7		7	All but tractor w/ backhoe, crane and vacuum-tank trailer(s) by C-130 A/C	Work Boat 1 Pump 1 Conveyor 1 Tank 1 P/W Separator 1 Crane 1 Truck 2
8		7	All but crane, truck-tractor and flat-bed trailer by C-130 A/C	Barges 2 Crane 1 Pump 1 Storage Tank 1 Truck 2

TABLE 47 (continued)

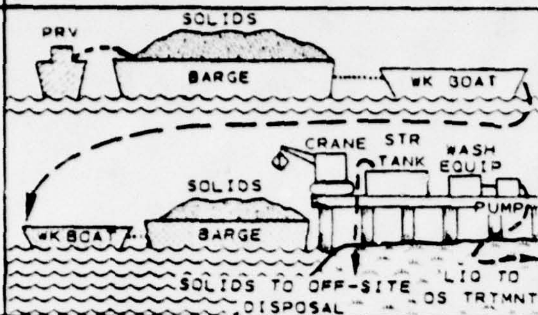
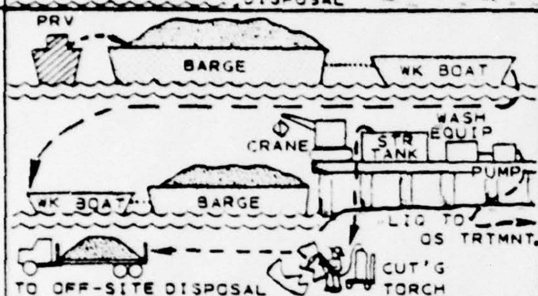
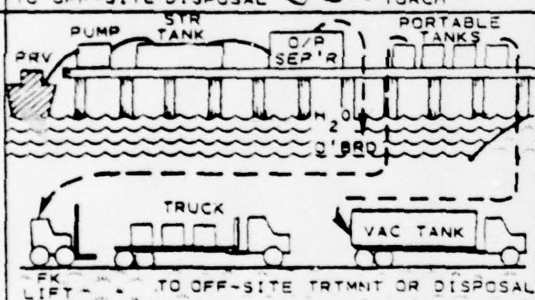
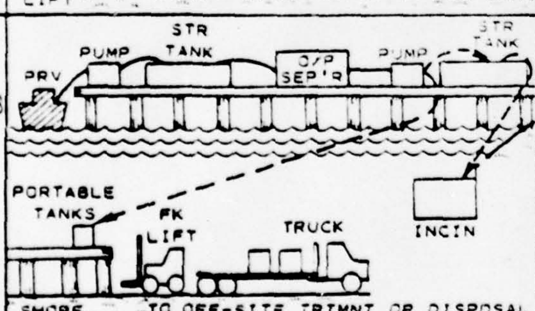
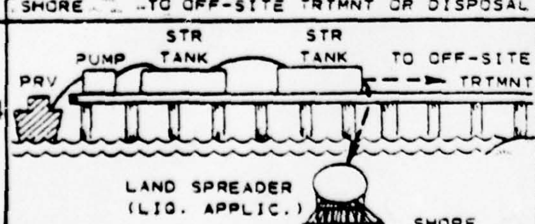
<table>
<tr><th rowspan="2">SYS-TEM</th><th rowspan="2">Schematic Diagram</th><th rowspan="2">OPTG PERS</th><th colspan="2">Compatibility w/USCG Equip</th></tr>
<tr><th>Transportation</th><th>Operation</th></tr>
<tr><td>9</td><td>
</td><td>7</td><td>All but crane, truck-tractor and flat-bed trailer by C-130 A/C</td><td>Barges 2
Crane 1
Pump 1
Storage Tank 1
Truck 2</td></tr>
<tr><td>13</td><td>
</td><td>7</td><td>Only the washing equipment and cutting torches can be moved by C-130 A/C</td><td>Pump 1
Work Boat 2
Crane 1
Welder 1
Driver/Pilots 2</td></tr>
<tr><td>OS-1</td><td>
</td><td>6</td><td>All but forklift, flat-bed trailer, vacuum tank and truck-tractor can be moved by C-130 A/C</td><td>Pump 1
Tank
(Erec/Monit) 2
P/W Separator 1
Truck 1
Fork Lift 1</td></tr>
<tr><td>OS-3</td><td>
</td><td>8</td><td>Same as OS-1</td><td>Pump 1
Tank
(Erec/Monit) 2
P/W Separator 1
Truck 1
Fork Lift 1
Incinerator
(Opr/Monit) 2</td></tr>
<tr><td>OS-4</td><td>
</td><td>5</td><td>All but liquid applicator vacuum-truck by C-130 A/C</td><td>Pump 1
Tank
(Erec/Monit) 2
Land Spred
(Opr/Monit) 2</td></tr>
</table>

TABLE 48. SUMMARY OF SPILL MASS HANDLING CAPABILITIES AND LIMITATIONS

RANGE				QUANTITY - PROCESSING RATE		
SYS. NO.	OIL GROUPS	FLOATING CHEMICAL GROUPS *	VOL. (m^3)	PROCESS PERIOD	LIMITING EQUIPMENT ITEM	THROUGHPUT RATE
1	I- All* II-All III-Low Visc. IV - All* V - All*	IVF-I - LTSF Only IVF-II-Nontoxic IVF-III-All INF-II,-III-All SNF&SVF - All	262	2 da	Incinerator	570 ℓ/hr
2	I - All II-All III-Low Visc. IV- All V - Low Visc.	IVF-I-Except LTSF IVF-II to-V -All INF-I to-III-All SNF - Nontoxic SVF - Nontoxic	303	2 da	Centrifugal Pump	500 ℓ/min (each)
4	I - All II - All III-Low Visc. IV - All V - All	IVF-I-Except LTSF IVF-II-Nontoxic IVF-IV,-V-All INF-I-to-III-All SNF,SVF-Nontoxic	490	2 da	Centrifugal Pump	500 ℓ/min (each)
7	I - All II - All III-Low Visc. IV-All V-Low Visc.	IVF-I to V-All, Except LTSF INF-I to III-All SNF-All† SVF-All†	180	4 hr	Tubular Conveyor	750 ℓ/min (26.5 cfm)
8	I - All II - All III-Low Visc. IV - All V - Low Visc.	IVF-I-Except LTSF IVF-II to-V-All INF-I to-III-All SNF - All# SVF - All#	3800	4-7 da**	Open-top roll-offs	(Capacity- 200 m^3 each)
9	I - All II - All III-Low Visc. IV - All V - Low Visc.	IVF-I-Except LTSF IVF-II to-V-All INF-I to III-All SNF - Nontoxic SVF - Nontoxic	3800	4-7 da**	Open-top roll-offs	(Capacity- 200 m^3 each)

*Appendices A and B

†Volatility can create explo-.on hazards during incineration.

#Protective clothing and face masks required for disposal crew.

**System modification to include the use of vapor-tight containers (for transfer of concentrated product) and protective clothing for disposal crew.

†It has been assumed that the volumetric ratio of solid debris to spilled product is 100 to 1 in warm conditions and 50 to 1 in cold weather. Thus, if a given amount of spilled oil, spilled in warm weather, requires 7 days, the same amount spilled in cold weather (slightly over half the overall volume, for warm conditions) should require about 4 days for the process period.

TABLE 48 (continued)

RANGE				QUANTITY - PROCESSING RATE		
SYS. NO.	OIL GROUPS	FLOATING CHEMICAL GROUPS	VOL. (m^3)	PROCESS PERIOD	LIMITING EQUIPMENT ITEM	THROUGHPUT RATE
13	I - All II - All III - All IV - All V - All	IVF-I thru -V INF-I thru -III SNF and SVF: See notes a. and b. below	(Wt - 4550 kg)	2 da (estim.)	Workboat Crane	(Cap'y-5 tons) (Lifting rad.- 23 ft)
OS-1	I - All II - All III-Low Visc. IV - All V - Low Visc.	IVF-I thru -V, INF-I thru -III, SNF and SVF: See note c. below	380	1 da	Oil/water sep. Pump-Pos.-Displ. Pump-Centrifugal	114,000 ℓ/hr (500 gpm) 40,000 ℓ/hr 32,000 ℓ/hr
OS-3	I - All II - All III-Low Visc. IV - All V - All	All IVF, INF, SNF and SVF: See and note c. below	86	8 da	Incinerator	450 ℓ/hr (2 gpm)
OS-4	(Same as Sys. OS-1)	(Same as System OS-1)	570	2 da (8-hr ea.)	Land cultivator (Liq.-Applic. Vac. Tank Truck)	2700 ℓ/min (700 gpm)

Notes:

a. Avoid chipping or flame-cutting where volatile chemicals are present until they are removed by washing operations.

b. Toxic chemicals must be removed from solid debris before shipment of the latter in open trucks or bins to final disposal.

c. For highly viscous oils and floating chemicals product/water separation is impractical. For these and low temperature solid floaters (LTSF), transport to an off-site disposal facility, or to System OS-4, is recommended.

TABLE 49. SUMMARY: DEVELOPMENT SCHEDULES AND COSTS

System	Development Time (months)	Development Labor (1,000 $)	Initial Capital (1,000 $)	Total Cost (1,000 $)	Difficulties/ Remarks
1	21	86	523	609	Incinerator development (at-sea use)
2	15	55	541	595	Portable ramp and oil/water separator
4	24	101	402	503	Pillow tanks, donut, tank truck
7	22	87	249	336	Processing/handling of fine solids on shore
8	24	90	962	1,052	Large system; over 70 major equipment items
9	21	89	893	962	Washing equipment, roll-off bins
13	21	75	504	579	Washing equipment
OS-1	15	53	246	299	On-shore oil/water separator and associated transport
OS-3	24	98	539	637	Incinerator development (on-shore use)
OS-4	15	61	101	162	Essentially a liquid applicator truck, plus pumps and storage

Existing disposal systems for oils and floating chemicals were evaluated for applicability to certain groups of hazardous chemicals. Limitations to such applications were defined as:

- Lack of safe, environmentally acceptable on-site disposal methods for highly hazardous materials

- Lack of adequate vapor containment techniques when transferring, storing, and treating materials that emit hazardous vapors

- Lack of effective, low-temperature washing techniques for debris contaminated with hazardous chemicals.

In order to improve handling and disposal capability, recommendations are made for modifications of existing systems. Essentially, these include improved storage for volatile and caustic wastes, and enhanced phase separation. Descriptions of new or conceptual equipment and systems for handling hazardous spill materials are included:

- Road-portable hazardous waste incinerator
- Sea-going hazardous waste incinerator
- Low-temperature debris-washing technique
- Bulk hazardous solids transport container
- Oil/water seal for hazardous material transport
- Field-sealable debris bags
- Nonsparking, corrosion-resistant crane and loader buckets
- Portable vapor containment system.

APPENDIX A

DEFINITION OF 5 GROUPS FOR 15 OILS AND 18 MISCELLANEOUS OILS

GROUP I

Density at 20°C is approximately 49 lb/ft^3
light viscosity
volatile or readily combustible

JP-1
JP-3
JP-5
OIL: FUEL: NO. 1
OIL: FUEL: NO. 1-D
OIL: RANGE
KEROSENE

GROUP II

Density at 20°C is approximately 53 lb/ft^3
lighter viscosity

OIL: CRUDE
OIL: DIESEL
OIL: FUEL: NO. 2
OIL: FUEL: NO. 2-D
OIL: ABSORPTION
OIL: LUBRICATING
OIL: MINERAL
OIL: MINERAL SEAL
OIL: ROSIN
OIL: SPERM
OIL: TALL
OIL: SPINDLE

GROUP III

Density at 20°C is approximately 57 lb/ft^3
heavier viscosity

ASPHALT
OIL: CRUDE
OIL: FUEL: NO. 4
OIL: FUEL: NO. 5
OIL: FUEL: NO. 6
OIL: MOTOR
OIL: NEATSFOOT ESTER
OIL: RESIN ESTER
OIL: ROAD
OIL: SPRAY
OIL: TANNER'S ESTER
OIL: TRANSFORMER
OIL: PENETRATING

GROUP IV

Density at 20°C is approximately 47 lb/ft^3
low viscosity
hazardous, flammable

JP-4

GROUP V

Density at 20°C is approximately 57 lb/ft^3
high viscosity
hazardous, flammable

OIL: COAL TAR - AEROMATICS

APPENDIX B

DEFINITION OF 6 GROUPS OF 167 OILS AND FLOATING CHEMICALS

TABLE B-1. CHEMICAL GROUP DESCRIPTIONS

IVF - Insoluble Volatile Floater:	Solubility below 0.01 lb/100 lb water at 60 to 70°F. Volatility indicated as a potential fire/explosion hazard by the CHRIS data. Flash point below 100°F.
INF - Insoluble Non-Volatile Floater:	Solubility below 0.01 lb/100 lb water at 60 to 70°F. Compounds are usually combustible, but not dangerously volatile.
SVF - Soluble Volatile Floater:	Compound exhibits some significant solubility in the water phase which may require further treatment following removal of floatables. Flash point below 100°F. Potential fire or explosion hazard indicated by CHRIS data.
SNF - Soluble Non-Volatile Floater:	Significant solubility in the water phase. Compounds are usually combustible, but do not represent an explosion hazard under normal handling conditions.
TF - Toxic Floater: (Compounds included in this set may also appear in other sets)	CHRIS data indicates requirements for special handling considerations due to toxic nature of the compound.
LTSF - Low Temperature "Solid" Floater:	Oils which become highly viscous at or near 0°C. Polymeric chemicals which become brittle at or near 0°C. Chemicals with freezing points at or near 0°C. All materials in this group present a need for special transfer equipment in scenarios exhibiting cold air temperatures.

TABLE B-2. SPECIFIC OILS AND CHEMICALS WITHIN EACH GROUP

GROUPS (See Appendix Table B-1 for key to compounds)

IVF	5	37	56	72	99	146	155	(49 compounds)
	12	44	57	73	118	147	156	
	13	51	58	77	136	148	163	
	15	52	60	80	137	149	164	
	31	53	61	93	139	151	165	
	33	54	63	95	143	152	166	
	36	55	69	96	144	153	167	
INF	8	30	67	92	108	120	131	(75 compounds)
	9	34	68	94	109	121	132	
	10	35	71	97	110	122	133	
	11	38	75	100	111	123	134	
	21	39	76	101	112	124	135	
	23	40	78	102	113	125	138	
	25	41	79	103	114	126	141	
	26	47	81	104	115	127	157	
	27	48	89	105	116	128	158	
	28	49	90	106	117	129		
	29	50	91	107	119	130		
SVF	1	19	46	83	150	161		(22 compounds)
	4	20	65	87	154	162		
	6	42	74	88	159			
	14	43	82	142	160			
SNF	2	18	45	66	85	145		(21 compounds)
	7	22	59	70	86			
	16	24	62	83	98			
	17	32	64	84	140			
TF	1	7	22	82	140	154	167	(25 compounds)
	2	12	24	85	142	156		
	3	19	43	88	150	165		
	4	11	49	90	151	166		

TABLE B-2 (continued)

<u>LTSF</u>	2	25	52	116	147	(30 compounds)
	3	27	68	123	151	
	7	29	70	135	157	
	9	38	81	138	163	
	10	40	94	140	164	
	12	47	104	146	167	

INSOLUBLE VOLATILE FLOATERS

<u>IVF - oils</u>

77

118

<u>IVF-I</u>

5	36	52*	57	69	96	149
13	37	53	58	72	99	153
15	44	54	60	73	136	155
31	50	55	61	80	137	
33	51	56	63	95	148	

<u>IVF-II</u>

12*	147*
93	151*
139	167*
146	

<u>TF</u>

156

165

166

*Low temperature "solid" floater: chemicals which tend to solidify at or near $0^{o}C$.

TABLE B-2 (continued)

IVF-III

152	163*	164*

INSOLUBLE NON-VOLATILE FLOATERS

INF - oils

8	100	112	117	123	128	133
75	101	113	119	124	129	134
76	102	114	120	125	130	
78	110	115	121	126	131	
79	111	116	122	127	132	

INF-I

23	39
26	40*
29*	81
30	158

TF

11
49

INF-II

21	28	38	67	89	94*	141
25	34	47*	68*	91	97	157
27	35	48	71*	92	135	

TF

90

INF-III

9	103	106	109
10*	104*	107	138
41	105	108	

*Low temperature "solid" floater: chemicals which tend to solidify at or near 0°C.

TABLE B-2 (continued)

SOLUBLE VOLATILE FLOATERS

SVF-I

6
87
159

TF

1
154

SVF-II

14
65
74

TF

4
19
150

SVF-III

42	161
83	162
160	

TF

43	88
82	142

SOLUBLE NON-VOLATILE FLOATERS

SNF-I

18	59	64	70*	98
32	62	66	86	

SNF-II

16	45
17	140*

SNF-III

2*	22	84	145
7*	24	85	

*Low temperature "solid" floater: chemicals which tend to solidify at or near $0^{o}C$.

TABLE B-3. KEY TO OILS AND CHEMICALS
LISTED IN TABLE B-2

1. Acrylonitrile
2. Adiponitrile
3. Aldrin
4. Allyl alcohol
5. Amyl acetate
6. n-Amyl alcohol
7. Aniline
8. Asphalt

Asphalt Blending Stocks:

9. - Roofers flux
10. - Straight run residue
11. Benzaldehyde
12. Benzene
13. Butadiene, inhibited
14. n-Butyl acetate
15. sec-Butyl acetate
16. n-Butyl acrylate
17. iso-Butyl acrylate
18. n-Butyl alcohol
19. tert-Butyl hydroperoxide
20. n-Butyraldehyde
21. Camphor oil
22. Cresols
23. Cumene
24. Cyclohexanone
25. Decaldehyde
26. 1-Decene
27. n-Decyl alcohol
28. Dibutyl phthalate
29. Dicyclopentadiene
30. Diethylbenzene
31. Diethyl carbonate
32. Diisobutyl carbinol
33. Diisobutylene
34. Dioctyl adipate
35. Dioctyl phthalate

Distillates:

36. - Straight run
37. - Flashed feed stocks
38. Dodecanol
39. Dodecene
40. Dowtherm
41. Epoxidized vegetable oils
42. Ethyl acetate
43. Ethyl acrylate
44. Ethylbenzene
45. Ethyl butanol
46. Ethyl ether
47. 2-Ethyl hexanol
48. Ethyl hexyl tallate
49. 2-Ethyl-3-propylacrolein
50. Gas oil: Cracked

Gasolines:

51. - Automotive (<4.23 g lead/gal)
52. - Aviation (<4.86 g lead/gal)
53. - Casinghead
54. - Polymer
55. - Straight run

Gasoline blending stocks:

56. - Alkylates
57. - Reformates
58. Heptane
59. Heptanol
60. 1-Heptene
61. Hexane
62. Hexanol
63. 1-Hexene
64. Isoamyl alcohol
65. Isobutyl acetate
66. Isobutyl alcohol
67. Isodecaldehyde
68. Isodecyl alcohol
69. Isohexane
70. Isooctyl alcohol
71. Isooctaldehyde
72. Isopentane
73. Isoprene
74. Isopropyl acetate

Jet fuels:

75. - JP-1 (Kerosene)
76. - JP-3
77. - JP-4
78. - JP-5 (Kerosene, heavy)
79. Kerosene
80. Lauryl mercaptan
81. Linear alcohols
82. Methyl acrylate
83. Methyl amyl acetate
84. Methyl amyl alcohol
85. Methylethylpyridine
86. Methyl isobutyl carbinol
87. Methyl isobutyl ketone
88. Methyl methacrylate
89. Mineral spirits

Naphtha:

90. - Coal tar
91. - Solvent
92. - Stoddard solvent
93. - VM&P (75% naphtha)

TABLE 3 (continued)

94. Nonanol
95. Nonene
96. 1-Nonene
97. Nonylphenol
98. Octanol
99. 1-Octene
Oils:
100. - Clarified
101. - Crude
102. - Diesel
Oils, edible:
103. - Castor
104. - Cottonseed
105. - Fish
106. - Olive
107. - Peanut
108. - Soya bean
109. - Vegetable
Oils, fuel:
110. - No. 1 (Kerosene)
111. - No. 1-D
112. - No. 2
113. - No. 2-D
114. - No. 4
115. - No. 5
116. - No. 6
Oils, miscellaneous:
117. - Absorption
118. - Coal tar
119. - Lubricating
120. - Mineral
121. - Mineral seal
122. - Motor
123. - Neatsfoot
124. - Penetrating
125. - Range
126. - Resin
127. - Rosin
128. - Sperm
129. - Spindle
130. - Spray
131. - Tall
132. - Tanner's
133. - Road
134. - Transformer
135. Pentadacanol
136. Pentane
137. 1-Pentene
138. Petrolatum
139. Petroleum naptha
140. Phenol
141. Polybutene
142. n-Propyl acetate
143. Propylene butylene polymer
144. Propylene tetramer
145. Styrene
146. Tallow
147. Tetradecanol
148. 1-Tetradecene
149. Tetrahydronaphthalene
150. Toluene
151. Toluene 2,4-Diisocyanate
152. Tridecanol
153. 1-Tridecene
154. Triethylamine
155. Triethylbenzene
156. Turpentine
157. Undecanol
158. 1-Undecene
159. Valeraldehyde
160. Vinyl acetate
161. Vinyl chloride
162. Vinyltoluene
Waxes:
163. - Carnauba
164. - Paraffin
165. o-Xylene
166. m-Xylene
167. p-Xylene

APPENDIX C

HAZARDOUS CHEMICALS INFORMATION

HAZARDOUS CHEMICALS

Categorization of the compounds on the hazardous chemicals list was based on physical parameters relevant to behavior in the aquatic environment and effects on human toxicity (exposure by inhilation). In addition, flammability-volatility is taken into account by use of the flash point to further categorize the compounds. Table C-1 is a listing of the 17 defined groups of hazardous chemicals. Table C-2 lists the compounds included within each group.

Solubility

The criterion for miscibility here is one percent solubility, on a weight/weight basis, at 20°C $\pm$ 5°. Therefore, "miscibility" in this context includes chemicals that are moderately or very soluble, as well as those soluble in all proportions in water - the strict definition of miscible. Given the proportions of solute and water that will generally exist in the spill situation, it is reasonable to expect most of the spill mass to be dissolved if it is soluble to the extent of one percent. Unpredictable variables affecting rate and extent of dissolution, i.e., mixing, temperature, and salinity, are not included in the solubility-miscibility estimation.

Reactive compounds are, in most cases, placed in miscible categories. Rates of reaction are usually not considered. On the other hand, certain sinkers, such as magnesium, which react very slowly,will not be designated as miscible, since these compounds do not solubilize significantly as a result of the reaction.

Though solubility in the CHRIS Manual is considered "not pertinent" in the case of reactive compounds, there are reasons for placing these compounds in the miscible category when considering disposal options. Several compounds are miscible by virtue of reactivity with water, and a great many others yield soluble reaction products. In many cases, the soluble reaction products,particularly HCI, HBr, and HF, are of primary concern with regard to the caustic and toxic behavior of the spill material; and classification of the parent compound as miscible thus recognizes the hazard potential of the form in which the compound will be handled in the disposal situation. In the case

of most of the unstable organic halides, the organic moiety will be released as a gas or floating liquid that is usually less hazardous than the hydrogen halide. In some reactions, especially for the metal compounds, one or more products may precipitate; an example is lead acetate from lead tetracetate. As is the case for certain parent compounds, product solubilities can vary widely with ambient conditions. It is anticipated that most precipitants will have formed prior to introduction to the handling/disposal operations. However, some metallic compounds may form a precipitate and can create problems for any operation, from containment to disposal.

There are compounds of variable composition or molecular weight, such as polypropylene glycol (MW 200-2,000 cations), which are categorized as miscible. Though, in some instances, they will behave otherwise, the higher members of a polymeric series will generally be less soluble.

The semiquantitative descriptor, "slightly soluble," is undefined in standard reference works, but is generally understood to encompass the range of 0.1 - 1.0 weight percent solubility. In cases where the only solubility data found was "slightly soluble," this assumption is made and the compound is placed in an immiscible category. Exceptions to this are found among some of the compounds placed in the miscible categories on the basis of reactivity.

Density and Phase State

The criterion for floatability is a specific gravity of less than 1.0 at standard pressure, and a temperature of $0^{o}C$. The higher density of sea water (specific gravity 1.03) is not considered, though in a few instances it may be a factor in flotation. CHRIS compounds of variable composition do not cover a large range of density, and there is usually no uncertainty as to their classification as floaters or sinkers. Reactive chemicals, as described above, are mostly classed as miscible, though reaction products may float or sink, or both [for instance, alkyl aluminum complexes yield a precipitate, $Al(OH)_3$, and a floating alkane].

Those liquid chemicals for which there is some prospect of a temperature-dependent phase transition during post-spill operations, fall into the Low Temperature Solid Sinker (LTSS) and Low Temperature Solid Miscible (LTSM) classes. These chemicals have freezing points above $0^{o}C$. Solubility or phase separation for these chemicals are unaffected by solidification, but the rates of dissolution or sinking are phase-dependent. No separate low temperature solid floater category is necessary.

Gases present the greatest difficulty in classification because their behavior is dependent on ambient conditions. Those few gases that are highly soluble, such as anhydrous ammonia, are found in the appropriate miscible grouping. Though they have a high vapor pressure, these gases will remain largely in solution during post-spill operations. Less certain is the disposition of immiscible gases, which have been split into two groups, Gas (G), and Dense Gas (DG). The criteria for a "dense gas" are that either the specific gravity of the condensed shipping state exceeds 1.0, or the vapor specific gravity exceeds 1.5, or both. These are compounds that will sink and boil, float and boil, and/or form a dense vapor cloud under proper conditions.

Though prospects for recovery of substantial amounts of these compounds presently are poor, continuing developmental efforts in collection equipment provide justification for considering them in disposal scenarios. In several instances,the boiling points are within the ambient range and two phases are likely to exist, allowing partial recovery. "Knockdown" sprays or foams may retard evaporation to the extent that recovery may be substantial despite low solubility. Since many of these chemicals fit both the liquid and gas phase density criteria, it is quire possible that they could persist as microbubbles through recovery operations, particularly if the water bears a high concentration of suspended particles providing adherent surfaces.

Those gases that are "light" in both condensed and gas phases (specific gravity less than 1.0 and vapor density less than 1.5), will disperse readily and cannot be embraced by any disposal option for recoverable spills. This does not imply that post-spill amelioration for light gases can be neglected. Liquified natural gas is in this category, and is commonly shipped in very large quantities. The gas classification simply indicates that no existing disposal option has been defined. Contained gases are most often treated for any incidental contamination,and are used as a re-graded fuel or blending stock.

<u>Volatility</u>

The only criterion used to classify these compounds with respect to volatility and flammability parameters is the flash point. If either flash point (closed cup or open cup) is equal to or less than 38°C (100°F), the compound is classified as volatile. For compounds that autoignite, such as alkyl aluminum complexes, flash point is undefined, but these are classed as volatile. While it is true that the measures of volatility are more strictly understood to be vapor pressure and boiling point, it can be recognized that high volatility is a necessary condition for definable flash point. Therefore, those chemicals with a flash point at or below 38°C (100°F) are both highly volatile

and highly flammable. Volatility is also used to define implicitly the Gas (G) and Dense Gas (DG) groups, regardless of flammability. Thus, nearly all compounds with a high vapor pressure fall into one of several gas and volatile categories, the most notable exception being highly soluble gases such as anhydrous ammonia (NH_3). Volatility is implicit for most of the toxic chemicals as well, insofar as threshold limit value is the parameter defining toxicity in this study, and TLV is most often based on vapor rather than solid particulate inhalation.

Causticity

Causticity is synonymous with corrosivity in its usage in this study, and is based almost entirely on Reactivity With Common Materials, identified in the CHRIS Manuals (59). Any compound that corrodes metals is placed in a caustic category, including those active only as aqueous solutes. Compounds reactive in a non-specific way towards plastics or other non-metals, are also classified as caustic. Conversely, compounds showing a specific mechanism of interaction limited to only a few materials, and unlikely to cause even light damage to equipment, are non-caustic. The pasticizer dissodecyl phthalate is an example. Compounds yielding corrosive products following reaction with water, and compounds that are only mildly corrosive, but which can be extremely hazardous nonetheless by virtue of their corrosive action, are deemed caustic. Azides, for instance, can form explosive metal complexes in pipes.

Tissue causticity is not used to identify caustic chemicals, but nearly all chemicals in the caustic groups are destructive of human tissue. Naturally, many chemicals noncorrosive to common materials are caustic to tissue, and one must refer to CHRIS data on individual chemicals to identify those chemicals with certainty. Tissue-corrosive chemicals that present a potential inhalation hazard are included in the toxic categories.

Toxicity

Toxicity is evaluated for the CHRIS compounds, and for the products resulting from their reaction with or dissolution in water. Thus, any compound likely to release such noxious products as phosphine, Cl, HCN, H_2S, and others in the presence of water, is placed in a toxic group. Generation of toxic products through fire, explosion, or corrosive activity is not considered on the assumption that proper handling methods will preclude their release to the environment. The bulk of CHRIS chemicals should be considered toxic in the event of uncontrolled combustion.

A Threshold Limit Value (TLV) of 100 ppm or less is the singular criterion of toxicity of those compounds and their reaction products for which a TLV has been established. Most of the

TLV's are time-weighted average (TWA), and a few are Short-Term Exposure Limit (STEL) or Ceiling (C) values. No distinction has been attempted, provided any one type of TLV meets the criterion. TLV's given in units of mg/cubic meter, referring to particulate exposures, were converted to ppm using the subject chemical molecular weight. In nearly every instance, the particulate TLV's converted to less than 100 ppm. For those compounds or their products for which a TLV has been set, this is the exclusive criterion.

Chemicals lacking a TLV were classified on the basis of one or more of several hazard ratings, toxicology data bases, and characterization in CHRIS, including recommendations for personal protective equipment. With few exceptions, the following criteria were applied in the order indicated to establish toxicity:

1. (NAS) National Academy of Sciences Vapor Irritant rating of 2 (moderate irritation; temporary effect) or above.

2. A rating in N.I. Sax, Dangerous Properties of Industrial Materials (49), of 2 (moderate effect) for acute exposure via inhalation, providing either local or systemic reactions. Chronic exposure and non-inhalation exposure routes were not considered.

3. A rating of 1 (slight effect; reversible) in either the NAS or Sax hazard ratings, combined with a stronger indicator of toxicity. These supplementary criteria include:

   (a) An NAS rating of 2 or greater as a poison (intermediate toxicity)

   (b) Evidence for carcinogenicity or co-carcinogenicity

   (c) Corrosive action

   (d) Short-term inhalation limits set at 500 ppm/30 min or less

   (e) CHRIS Personal Protective Equipment specifying any form of respiratory protection more stringent than a dust mask (self-contained breathing apparatus, air-supplied mask, organic cannister mask)

   (f) Any other information suggesting that a rating of 1 may underestimate personal hazard risks.

4. For those compounds lacking specific ratings, a rating of 2 or greater in Sax for compounds of that class,

generally neglecting exposure route but considering only acute exposure. For example, oxalates, fluoborates, fluosilicates, organic peroxides hydrazines and hydrazine mercaptans, and silanes range from moderately to extremely toxic,and all memb rs of these groups from the CHRIS list were so categorized. The Sax ratings were corroborated using several other sources.

Clarification of the methodology applied to mixtures and to solids, especially salts, is useful. Mixtures are toxic if any compound present in appreciable amounts is toxic. In some cases, especially for gasolines (see "Floaters"), composition is too variable, particularly for benzene in the gasolines, for a single TLV to be applicable. Generally, criteria other than TLV could be used to establish the most prevalent situation, and most CHRIS mixtures are, in fact, nontoxic. No attempt has been made to consider additive or synergistic effects. With regard to solids, there may be some question as to the appropriateness to the miscible compounds of a particulate TLV expressed in mg/cubic meter. Compounds such as acrylamide (TLV 0.3 mg/m^3) are so acutely or extremely toxic that, despite low vapor pressure, they are a definite hazard in either dry or wet form.

Most of the toxic salts, that is, heavy metal salts or salts with hazardous anions, are not nearly so acutely toxic and may only be irritants on acute exposure via inhalation. These are chemicals for which a dust mask is recommended for exposure to solid forms. Though personal risk is greatly reduced when the toxic salts are dissolved or submerged in water, any inorganic or other solid compound for which the particulate TLV is equivalent to 100 ppm or less is classified as toxic. This categorization recognizes the potential hazard solutions of these compounds present, should they be sprayed, vaporized as aerosols, or dried at any point during the handling and disposal scenarios.

As is the case for any system of hazardous substances classification, the "toxic" designation used here is only a guide, and no fine line between safe and hazardous chemicals or concentrations is intended. Disposal scenarios, likewise, cannot unambigously be fashioned to treat "toxic" or "nontoxic" compounds. The range of physiological responses, from lacrymation, to irreversible central nervous system disorders, to death, is too wide to allow unequivocal classification in all circumstances. It is recognized that certain substances in the CHRIS Manual are considered harmful for reasons other than toxicity (i.e. - propylene, a simple asphyxiant). The present classification system attempts to establish criteria and interpret data such that only those compounds for which there is some health risk in acute inhalation exposure have been identified and placed in a toxic group.

TABLE C-1. DEFINITION OF 17 GROUPS OF 900 HAZARDOUS CHEMICALS

S - Sinker	Specific gravity $\geq$ 1.00 at 25°C $\pm$ 5°.
VS - Volatile Sinker	Specific gravity $\geq$ 1.00 at 25°C $\pm$ 5°. Flash point (open cup or closed cup) $\leq$ 38°C (100°F).
TS - Toxic Sinker	Specific gravity $\geq$ 1.00 at 25°C $\pm$ 5°. Threshold limit value (TLV) equivalent to 100 ppm or less assigned, or other indications of mild to severe toxic or irritating effects on humans.
TVS - Toxic Volatile Sinker	Specific gravity $\geq$ 1.00 at 25°C $\pm$ 5°. TLV $\leq$ 100 ppm or other indications of mild to severe toxic or irritating effects. Flash point (O.C. or C.C.) $\leq$ 38°C (100°F).
TCS - Toxic Caustic Sinker	Specific gravity $\geq$ 1.00 at 25°C $\pm$ 5°. Corrosive towards common construction materials, generally metals. TLV $\leq$ 100 ppm or other indications of mild to severe toxic or irritating effects.
LTSS - Low Temperature Solid Sinker	Specific gravity $\geq$ 1.00 at 25°C $\pm$ 5°. Freezing point above 0°C (32°F).
M - Miscible	Solubility or miscibility greater than 1% (weight solute/weight water) in pure water at 25°C $\pm$ 5°, or chemical reacts with water to form at least one soluble product.
CM - Caustic Miscible	Soluble in or reactive with water (see Miscible). Corrosive towards common construction materials, generally metals.
VM - Volatile Miscible	Soluble in or reactive with water (see Miscible). Flash point (O.C. or C.C.) $\leq$ 38°C (100°F).
VCM - Volatile Caustic Miscible	Soluble in or reactive with water (see Miscible). Flash point (O.C. or C.C.) $\leq$ 38°C (100°F). Corrosive towards common construction materials, generally metals.

TABLE C-1 (continued)

TM - Toxic Miscible	Soluble in or reactive with water (see Miscible). TLV $\leq$ 100 ppm or other indications of toxic or irritating effects.
TCM - Toxic Caustic Miscible	Soluble in or reactive with water (see Miscible). TLV $\leq$ 100 ppm or other indications of toxic or irritating effects. Corrosive towards common construction materials generally metals.
TVM - Toxic Volatile Miscible	Soluble in or reactive with water (see Miscible). TLV $\leq$ 100 ppm or other idications of toxic or irritating effects. Flash point (O.C. or C.C.) $\leq$ 38°C (100°F).
TVCM - Toxic Volatile Caustic Miscible	Soluble in or reactive with water (see Miscible). TLV $\leq$ 100 ppm or other indications of toxic or irritating effects. Flash point (O.C. or C.C.) $\leq$ 38° C (100°F). Corrosive towards common construction materials, generally metals.
LTSM - Low Temperature Solid Miscible	Soluble in or reactive with water (see Miscible). Freezing point above 0°C (32°F).
G - Gas	Boiling point below 25°C (77°F). Vapor specific gravity (air) below 1.50. Specific gravity (water) of shipping state, solid, liquid, or compressed gas, below 1.00. May be toxic or volatile, that is TLV $\leq$ 100 ppm or flash point $\leq$ 38°C (100°F), as indicated for each compound.
DG - Dense Gas	Boiling point below 25°C (77°F). Vapor specific gravity (air) $\geq$ 1.50 or specific gravity (water) of shipping state, solid, liquid, or compressed gas, $\geq$ 1.00. May be toxic or volatile, that is TLV $\leq$ 100 ppm or flash point $\leq$ 38°C (100°F), as indicated for each compound.

TABLE C-2. HAZARDOUS CHEMICAL GROUPS

GROUPS*								
S	79	107	170	200	437	719	836	(35 compounds)
	92	109	172	231	499	753	837	
	93	114	177	238	532	800	841	
	94	125	178	240	614	806	851	
	96	127	185	311	706	834c	890	
VS	232							(2 compounds)
	283							
TS	13	166	234	293	453	553	716	(99 compounds)
	20	168	237	295	482	586	758	
	28	171	243	300	518	592	760	
	85	189	252	324	521	598	762	
	87	190	258	329	524	600	763	
	90	195	259	331	528	607	791	
	95	201	267	332	536	617	811	
	104	204	272	333	537	618	812	
	119	206	277	334	539	619	819	
	123	208	278	340	542	625	838	
	126	209	279	342	544	688	850	
	135	213	280	343	545	691	868	
	136	226	286	361	546	712	885	
	156	229	287	451	548	715	889	
							897	
TCS	74	110	130	520	826			(17 compounds)
	105	113	131	523				
	106	115	253	698				
	108	116	281	825				
TVS	23	289	392	833				
	25c	290	605	835				(15 compounds)
	271	383	707	873				
	288	384c	824					
LTSS	7	506c	620t					
	215t	534t	689t					(11 compounds)
	391t	566t	882t					
	457tc	579t						

*See Appendix Table C-1 for key compounds.

TABLE C-2 (continued)

M	18	53	174	345	450	765	810	(111 compounds)
	21	54	180	353	458	766	817	
	29	58	183	354	459	771	827	
	30	59	224	355	463	772	840	
	33	61	233	356	513	775	847	
	34	63	235	357	514	780	855	
	35	66	236	358	530	781	864	
	37	67	268	367	535	782	869	
	39	68	285	370	552	787	883	
	43	111	301	371	683	789	884	
	46	117	302	373	684	790	887	
	47	118	303	394	693	792	891	
	49	158	304	399	719	793	892	
	50	161	305	411	720	794	893	
	51	162	306	431	724	795	896	
	52	173	337	440	743	798		
CM	179	244	732	785				(14 compounds)
	198	452	764	803				
	199	713	773					
	218	730	784					
VM	1	352	396	554	621	866		(21 compounds)
	4	372	404	557	739			
	146	375	501	569	740			
	147	395	502	571	822			
VCM	624							(1 compound)
TM	5	99	216	393	522	686	776	(169 compounds)
	12	100	219	397	533	690	777	
	16	101	220	398	538	701	778	
	22	112	221	400	540	703	788	
	31	121	222	401	541	704	809	
	38	124	225	414	547	709	818	
	40	128	227	420	560	721	848	
	41	129	228	421	570	722	853	
	42	148	239	424	574	723	861	
	45	149	245	427	577	725	862	
	48	150	247	428	581	726	863	
	55	163	251	429	591	727	865	
	56	164	269	430	593	728	886	
	57	165	273	435	602	731	888	
	60	167	284	438	603	735	894	
	62	169	292	439	604	745	895	
	65	175	297	449	606	750	899	
	77	176	307	478	608	751	900	
	82	181	317	479	609	752		
	84	182	319	480	610	757		
	86	184	321	481	611	759		
	88	191	323	483	612	761		
	89	197	378	498	613	767		
	97	205	387	503	617	768		
	98	212	388	517	626	769		

TABLE C-2 (continued)

TCM	9	157	417	475	616	733	805	(80 compounds)
	27	202	423	476	623	737	816	
	36	203	425	489	628	738	820	
	44	214	426	519	685	754	828	
	76	217	432	529	696	755	831	
	78	230	433	531	697	756	856	
	83	310	434	543	702	770	867	
	120	326	461	558	705	774	898	
	122	341	469	565	708	786		
	132	359	470	580	710	801		
	133	415	472	587	711	802		
	134	416	473	615	729	804		
TVM	3	159	320	402	490	578	832	(48 compounds)
	6	160	327	403	549	584	845	
	8	207	330	405	556	627	849	
	14	210	344	412	563	736	852	
	70	241	362	474	572	744	870	
	145	254	374	486	573	746	874	
	152	309	389	487	575	749		
TVCM	10	153	377	568	876			(17 compounds)
	17	211	385	583				
	26	322	420	839				
	64	376	462	854				
LTSM	2tc	139	296	366	467tc	717c		(24 compounds)
	15t	140	316t	368	468tc	783tc		
	80tc	188t	328	369	589t	799		
	81tc	250t	338tv	436	590t	844		
G	11	471v	662					(11 compounds)
	194t	477t	687					
	364v	526v	821t					
	386v	551v						
DG	192	282	527	629				(16 compounds)
	193tv	291t	562t	734v				
	246t	484tv	564t	741v				
	248t	488t	588	871tv				

Notes: t - toxic
v - volatile
c - caustic

TABLE C-2. CHRIS CHEMICALS

	Chemical Name	Chris Code		Chemical Name	Chris Code
1.	Acetaldehyde	AAD	47.	Ammonium Lauryl Sulfate	ALS
2.	Acetic Acid	AAC	48.	Ammonium Molybdate	AMB
3.	Acetic Anhydride	ACA	49.	Ammonium Nitrate	AMN
4.	Acetone	ACT	50.	Ammonium Nitrate - Carbonate Mix	ANC
5.	Acetone Cyanohydrin	ACY	51.	Ammonium Nitrate - Phosphate Mix	ANP
6.	Acetonitrile	ATN	52.	Ammonium Nitrate - Sulfate Mix	ANS
7.	Acetophenone	ACP	53.	Ammonium Nitrate - Urea Solution	ANU
8.	Acetylacetone	ATA	54.	Ammonium Oleate	AOL
9.	Acetyl Bromide	ABM	55.	Ammonium Oxalate	AOX
10.	Acetyle Chloride	ACC	56.	Ammonium Pentaborate	APB
11.	Acetylene	ACE	57.	Ammonium Perchlorate	AMP
12.	Acetyl Peroxide Solution	APS	58.	Ammonium Persulfate	APE
13.	Acridine	ACD	59.	Ammonium Phosphate	APP
14.	Acrolein	ARL	60.	Ammonium Silicofluoride	ASL
15.	Acrylic Acid	ACR	61.	Ammonium Stearate	AMR
16.	Acrylamide	AAM	62.	Ammonium Sulfamate	ASM
17.	Acrylonitrile	ACN	63.	Ammonium Sulfate	AMS
18.	Adapic Acid	ADA	64.	Ammonium Sulfide	ASF
19.	Adiponitrile	ADN	65.	Ammonium Sulfite	AMF
20.	Aldrin	ALD	66.	Ammonium Tartrate	ATR
21.	Alkylbenzenesulfonic Acids	ABS	67.	Ammonium Thiocyanate	AMT
22.	Allyl Alcohol	ALA	68.	Ammonium Thiosulfate	ATF
23.	Allyl Bromide	ABR	69.	Amyl Acetate (N-)	AML
24.	Allyl Chloride	ALC	70.	Amyl Alcohol (N-)	AAN
25.	Allylchloroformate	ACF	71.	Amyl Chloride (N-)	AMY
26.	Allyl Trichlorosilane	ATC	72.	Amyl Mercaptan (N-)	AMM
27.	Aluminum Chloride	ACL	73.	Amyl Methyl Ketone (N-)	AMK
28.	Aluminum Fluoride	ALF	74.	Amylnitrate (N-)	ANT
29.	Aluminum Nitrate	ALN	75.	Amyl Nitrite (ISO)	ANI
30.	Aluminum Sulfate	ALM	76.	Amyltrichlorosilane (N-)	ATS
31.	Aminoethanolamine (N-)	AEA	77.	Aniline	ANL
32.	Ammonia Anhydrous	AMA	78.	Anisoyl Chloride	ASC
33.	Ammonium Acetate	AAT	79.	Anthracene	ATH
34.	Ammonium Benzoate	ABZ	80.	Antimony Pentachloride	APC
35.	Ammonium Bicarbonate	ABC	81.	Antimony Pentafluoride	APF
36.	Ammonium Bifluoride	ABF	82.	Antimony Potassium Tartrate	APT
37.	Ammonium Carbonate	ACB	83.	Antimony Trichloride	ATM
38.	Ammonium Chloride	AMC	84.	Antimony Trifluoride	ATT
39.	Ammonium Citrate	ACI	85.	Antimony Trioxide	ATX
40.	Ammonium Dichromate	AMD	86.	Arsenic Acid	ASA
41.	Ammonium Fluoride	AFR	87.	Arsenic Sulfide (DI)	ARD
42.	Ammonium Formate	AFM	88.	Arsenic Trichloride	AST
43.	Ammonium Gluconate	AGC	89.	Arsenic Trioride	ATO
44.	Ammonium Hydroxide. 28 Percent Aq.	AMH	90.	Arsenic Trisulfide	ART
45.	Ammonium Iodide	AID			
46.	Ammonium Lactate	ALT			

CHRIS CHEMICALS (continued)

	Chemical Name	Chris Code		Chemical Name	Chris Code
91.	Asphalt	ASP	130.	Boron Trichloride	BRT
92.	Asphalt Blending Stocks: Roofers Flux	ARF	131.	Boron Tribromide	BTB
93.	Asphalt Blending Stocks: Straight Run Residue	ASR	132.	Bromine	BRX
94.	Atrazine	ATZ	133.	Bromine Pentafluoride	BPF
95.		AZM	134.	Bromine Trifluoride	BTF
96.	Bapium Carbonate	BRC	135.	Bromobenzene	BBZ
97.	Barium Chlorate	BCR	136.	Brucine	BRU
98.	Barium Nitrate	BNT	137.	Butadiene Inhibited	BDI
99.	Barium Perchlorate	BPC	138.	Butane	BUT
100.	Barium Permanganate	BPM	139.	1.4-Butanediol	BDO
101.	Barium Peroxide	BPO	140.	1.4-Butenediol	BUD
102.	Benzaldehyde	BZD	141.	Butyl Acetate (N-)	BCN
103.	Benzene	BNZ	142.	Butyl Acetate (Sec-)	BTA
104.	Benzene Hexachloride	BHO	143.	Butyl Acrylate (Iso-)	BAI
105.	Benzene Phosphorus Dichloride	BPD	144.	Butyl Acrylate (N-)	BTC
106.	Benzene Phosphorus Thiodichloride	BPT	145.	Butyl Alcohol (N-)	BAN
107.	Benzoic Acid	BZA	146.	Butyl Alcohol (Sec-)	BAS
108.	Benzonitrile	BZN	147.	Butyl Alcohol (Tert-)	BAT
109.	Benzophenone	BZP	148.	Butylamine (N-)	BAM
110.	Benzoyl Chloride	BZC	149.	Butylamine (Sec-)	BTL
111.	Benzyl Alcohol	BAL	150.	Butylamine (Ter-)	BUA
112.	Benzylamine	BZM	151.	Butylene	BTN
113.	Benzyl Bromide	BBR	152.	1.2-Butylene Oxide	BTO
114.	Benzyl N-Butyl Phthalate	BBP	153.	Butyl Hydroperoxide (Tert-)	BHP
115.	Benzyl Chloride	BCL	154.	Butyl Mercaptan (N-)	BTM
116.	Benzyl Chloroformate	BCF	155.	Butyl Methacrylate (N-)	BMN
117.	Benzyldimethylocta-Decylammonium Chloride	BZO	156.	Butylphenol (P-Tert-)	BTP
118.	Benzyltrimethylam-monium Chloride	BMA	157.	Butyltrichlorosilane	BCS
119.	Beryllium Metallic	BEM	158.	1.4-Butynediol	BTD
120.	Beryllium Chloride	BEC	159.	Butyraldehyde (N-)	BTR
121.	Beryllium Fluoride	BEF	160.	Butyraldehyde (Iso-)	BAD
122.	Beryllium Nitrate	BEN	161.	Butyric Acid (N-)	BRA
123.	Beryllium Oxide	BEO	162.	Cacodylic Acid	CDA
124.	Beryllium Sulfate	BES	163.	Cadmium Acetate	CAT
125.	Bismuth Oxychoride	BOC	164.	Cadmium Bromide	CMB
126.	Bisphenol A	BPA	165.	Cadmium Chloride	CDC
127.	Bisphenol A Diglycidyl Ether	BDE	166.	Cadmium Fluoborate	CFB
128.	Boiler Compount - Liquid	BCP	167.	Cadmium Nitrate	CMN
129.	Boric Acid	BAC	168.	Cadmium Oxide	COX
			169.	Cadmium Sulfate	CMS
			170.	Calcium Metallic	CAM
			171.	Calcium Arsenate	CCA
			172.	Calcium Carbide	CCB
			173.	Calcium Chlorate	CCC
			174.	Calcium Chloride	CLC
			175.	Calcium Chromate	CCR
			176.	Calcium Cyanide	CCN
			177.	Calcium Fluoride	CAF
			178.	Calcium Hydroxide	CAH

CHRIS CHEMICALS (continued)

	Chemical Name	Chris Code		Chemical Name	Chris Code
179.	Calcium Hypochlorite	CHY	226.	Copper Arsenite (IC)	CPA
180.	Calcium Nitrate	CNT	227.	Copper Bromide (IC)	CPB
181.	Calcium Oxide	CAO	228.	Copper Chloride (IC)	CPC
182.	Calcium Peroxide	CCP	229.	Copper Cyanide (OUS)	CCY
183.	Calcium Phosphate	CAL	230.	Copper Fluoborate (IC)	CPF
184.	Calcium Phosphide	CPP	231.	Copper Iodide (OUS)	CID
185.	Calcium Resinate	CRE	232.	Copper Napthenate (IC)	CNN
186.	Camphene	CPH	233.	Copper Nitrate (IC)	CNI
187.	Camphor (oil)	CPO	234.	Copper Oxalate (IC)	COL
188.	Caprolactam (Solution)	CLS	235.	Copper Sulfate (IC)	CSF
189.	Captan	CPT	236.	Corn Syrup	CSY
190.	Carbaryl	CBY	237.	Coumaphos	COU
191.	Carbolic Oil	CBO	238.	Creosote Coal Tar	CCT
192.	Carbon Dioxide	CDO	239.	Cresols	CRS
193.	Carbon Disulfide	CBB	240.	Cresyl Glycidyl Ether	CGE
194.	Carbon Monoxide	CMO	241.	Crotonaldehyde	CTA
195.	Carbon Tetrachloride	CBT	242.	Cumene	CUM
196.	Carene	CAR	243.	Cumene Hydroperoxide	CMH
197.	Catechol	CTC	244.	Cupriethylenediamine Solution	CES
198.	Caustic Potash. Solution	CPS	245.	Cyanoacetic Acid	CYA
199.	Caustic Soda Solution	CSS	246.	Cyanogen	CYG
200.	Charcoal	CHC	247.	Cyanogen Bromide	CBR
201.	Chlordane	CDN	248.	Cyanogen Chloride	CCL
202.	Chlorine	CLX	249.	Cyclohexane	CHX
203.	Chlorine Trifluoride	CTF	250.	Cyclohexanol	CHN
204.	Chloroacetophenone	CRA	251.	Cyclohexanone	CCH
205.	Chloroacetyl Chloride	CAC	252.	Cyclohexanone Peroxide	CHP
206.	Chloroaniline (P-)	CAP	253.	Cyclohexanyltrichlorosilane	CHT
207.	Chlorobenzene	CRB	254.	Cyclohexylamine	CHA
208.	4-Chlorobutyronitrile	CBN	255.	Cyclopentane	CYP
209.	Chloroform	CRF	256.	Cyclopropane	CPR
210.	Chlorohydrin (Crude)	CHD	257.	Cymene (P-)	CMP
211.	Chloromethyl Methyl Ether	CME	258.	2.4-D (Esters)	DES
212.	Chlorophenol (P-)	CPN	259.	DDD	DDD
213.	Chloropicrin (Liquid)	CPL	260.	DDT	DDT
214.	Chlorosulfonic Acid	CSA	261.	Decaborane	DBR
215.	4-Chloro-O-Toluidine	CTD	262.	Decahydronaphtalene	DHN
216.	Chromic Anhydride	CMA	263.	Decaldehyde	DAL
217.	Chromyl Chloride	CMC	264.	1-Decene	DCE
218.	Citric Acid	CIT	265.	Decyl Alcohol	DAN
219.	Cobalt Acetate (OUS)	CBA	266.	Decylbenzene (N-)	DBZ
220.	Cobalt Chloride (OUS)	CBC	267.	Demeton	DTN
221.	Cobalt Nitrate (OUS)	CON	268.	Dextrose Solution	DTS
222.	Cobalt Sulfate (OUS)	CBS	269.	Diacetone Alcohol	DAA
223.	Collodion	CLD	270.	Di-N-Amyl Phthalate	DAP
224.	Copper Acetate (IC)	COP	271.	Diazinon	DZN
225.	Copper Acetoarsenite (IC)	CAA	272.	Dibenzoyl Peroxide	DPO
			273.	Di-N-Butylamine	DBA

	Chemical Name	Chris Code		Chemical Name	Chris Code
274.	Di-N-Butyl Ether	DBE	311.	Diheptyl Phthalate	DHP
275.	Di-N-Butyl Ketone	DBK	312.	Diisobutylcarbinol	DBC
276.	Dibutylphenol	DBT	313.	Diisobutylene	DBL
277.	Dibutyl Phthalate	DPA	314.	Diisobutyl Ketone	DIK
278.	Dichlorobenzene (O-)	DBO	315.	Diisodecyl Phthalate	DID
279.	Dichlorobenzene (P-)	DBP	316.	Diisopropanolamine	DIP
280.	Di-(p-Chlorobenzoyl) Peroxide	DZP	317.	Diisopropylamine	DIA
281.	Dichlorobutene	DCB	318.	Diisopropylbenzene Hydroperoxide	DIH
282.	Dichlorodifluoro-methane	DCF	319.	Dimethylacetamide	DAC
283.	1.2-Dichloroethylene	DEL	320.	Dimethylamine	DMA
284.	Dichloroethyl Ether	DEE	321.	Dimethyl Ether	DIM
285.	Dichloromethane	DCM	322.	Dimethyldichlorosilane	DMD
286.	2.4-Dichlorophenol	DCP	323.	Dimethylformamide	DMF
287.	2.4-Dichlorophenoxy-acetic Acid	DCA	324.	Dimethylhexane Dihydro-peroxide. Wet	DDW
288.	Dichloropropane(1.2-)	DPP	325.	Dimethylpolysiloxane	DMP
289.	Dichloropropene	DPR	326.	Dimethyl Sulfate	DSF
290.	4.4-Dichloro-Alpha-Trichloromethyl-Benzhydrol	DTM	327.	Dimethyl Sulfide	DSL
			328.	Dimethyl Sulfoxide	DMS
			329.	Dimethyl Terephthalate	DMT
			330.	Dimethylzinc	DMZ
291.	1.2-Difluoroethane	DFE	331.	Dinitrobenzene (M-)	DNB
292.	1.2-Dimethylhydrazine	DMH	332.	Dinitrocresols	DNC
293.	2.4-Dinitroaniline	DNT	333.	2.4-Dinitrophenol Diisocyanate	DNP
294.	Dicyclopentadiene	DPT			
295.	Dieldrin	DED	334.	2.4-Dinitrotoluene	DTT
296.	Diethanolamine	DEA	335.	Dioctyl Adipate	DOA
297.	Diethylamine	DEN	336.	Dioctyl Phthalate	DOP
298.	Diethylbenzene	DEB	337.	Dioctyl Sodium Sulfosuccinate	DSS
299.	Diethyl Carbonate	DEC			
300.	Diethyl Phthalate	DPH	338.	Dioxane (1.4-)	DOX
301.	Diethylene Glycol	DEG	339.	Dipentene	DPN
302.	Diethylene Glycol Dimethyl Ether	DGD	340.	Diphenylamine	DAM
			341.	Diphenyldichilorosilane	DPD
303.	Diethylene Glycol Monobutyl Ether	DME	342.	Diphenyl Ether	DPE
			343.	Diphenylmethane Diiso-cyanate	DPM
304.	Diethylene Glycol Monobutyl Ether Acetate	DEM	344.	Di-N-Propylamine	DNA
			345.	Dipropylene Glycol	DPG
305.	Diethylene Glycol Monoethyl Ether	DGE	346.	Distillates: Flashed Feed Stocks	DFF
306.	Diethylene Glycol Monomethyl Ether	DGM	347.	Distillates: Straight Run	DSR
307.	Diethylenetriamine	DET	348.	Dodecanol	DDN
308.	Di-(2-Ethylhexyl) Phosphoric Acid	DEP	349.	1-Dodecene	DDC
			350.	Dodecene	DOD
309.	Diethylzinc	DEZ	351.	Dodecylbenzene	DDB
310.	Difluorophosphoric Acid. Anhydrous	DFA	352.	Dodecylbenzenesulfonic Acid. Calcium Salt	DCS

	Chemical Name	Chris Code
353.	Dodecylbenzenesulfonic Acid. Isopropylamine Salt	DAI
354.	Dodecylbenzenesulfonic Acid. Triethanolamine Salt	DBS
355.	Dodecyl Sulfate. Diethanolamine Salt	DSD
356.	Dodecyl Sulfate. Magnesium Salt	DSM
357.	Dodecyl Sulfate. Sodium Salt	DDS
358.	Dodecyl Sulfate. Triethanolamine Salt	DST
359.	Dodecyltrichlorisilane	DTC
360.	Dowtherm	DTH
361.	Endrin	EDR
362.	Epichlorohydrin	EPC
363.	Epoxidized Vegetable Oils	EVO
364.	Ethane	ETH
365.	Ethoxydihydropyran	EHP
366.	Ethoxylated Dodecanol	EOD
367.	Ethoxylated Nonylphensol	ENP
368.	Ethoxylated Pentadecanol	EOP
369.	Ethoxylated Tetradecanol	EOT
370.	Ethoxylated Tridecanol	ETD
371.	Ethoxy Triglycol	ETG
372.	Ethyl Acetate	ETA
373.	Ethyl Acetoacetate	EAA
374.	Ethyl Acrylate	EAC
375.	Ethyl Alcohol	EAL
376.	Ethylaluminum Dichloride	EAD
377.	Ethylaluminum Sesquichloride	EAS
378.	Ethylamine	EAM
379.	Ethylbenzene	ETB
380.	Ethyl Butanol	EBT
381.	Ethyl Butyrate	EBR
382.	Ethyl Chloride	ECL
383.	Ethyl Chloroacetate	ECA
384.	Ethyl Chloroformate	ECF
385.	Ethyldichlorosilane	ECS
386.	Ethylene	ETL
387.	Ethylene Chlorohydrin	ECH
388.	Ethylene Cyanohydrin	ETC
389.	Ethylenediamine	EDA
390.	Ethylenediamine Tetracetic Acid	EDT
391.	Ethylene Dibromide	EDB
392.	Ethylene Dichloride	EDC
393.	Ethylene Glycol	EGL
394.	Ethylene Glycol Diadetate	EGY
395.	Ethylene Glycol Diethyl Ether	EEE
396.	Ethlene Glycol Dimethyl Ether	EGD
397.	Ethylene Glycol Monobutyl Ether	EGM
398.	Ethylene Glycol Monobutyl Ether Acetate	EMA
399.	Ethylene Glycol Mono-Ethyl Ether	EGE
400.	Ethylene Glycol Monethyl Ether Acetate	EGA
401.	Ethylene Glycol Monomethyl Ether	EME
402.	Ethyleneimine	ETI
403.	Ethylene Oxide	EOX
404.	Ethyl Ether	EET
405.	Ethyl Formate	EFM
406.	Ethylhexaldehyde	EHA
407.	Ethyl Hexanol (2-)	EHX
408.	2-Ethylhexl Acrylate. Inhibited	EAI
409.	Ethylhexyl Tallate	EHT
410.	Ethylidenenorbornene	ENB
411.	Ethyl Lactate	ELT
412.	Ethyl Mercaptan	EMC
413.	Ethyl Methacrylate	ETM
414.	Ethyl Nitrite	ETN
415.	Ethylphenyldichlorosilane	EPS
416.	Ethyl Phosphonothioic Dichloride. Anhydrous	EPD
417.	Ethyl Phosphorsdichloridate	EPP
418.	2-Ethyl-3-Propylacrolein	EPA
419.	Ethyl Silicate	ESC
420.	Ethyltrichlorosilane	ETS
421.	Ferric Ammonium Citrate	FAC
422.	Ferric Ammonium Oxalate	FAO
423.	Ferric Chloride	FCL
424.	Ferric Glycerophosphate	FCP

CHRIS CHEMICALS (continued)

	Chemical Name	Chris Code
425.	Ferric Nitrate	FNT
426.	Ferric Sulfate	FSF
427.	Ferrous Ammonium Sulfate	FAS
428.	Ferrous Chloride	FEC
429.	Ferrous Fluoborate	FFB
430.	Ferrous Oxalate	FOX
431.	Ferrous Sulfate	FRS
432.	Fluorine	FXX
433.	Fluosilicic Acid	FSL
434.	Fluosulfonic Acid	FSA
435.	Formaldehyde Solution	FMS
436.	Formic Acid	FMA
437.	Fumaric Acid	FUM
438.	Furfural	FFA
439.	Furfuryl Alcohol	FAL
440.	Gallic Acid	GLA
441.	Gas Oil: Cracked	GOC
442.	Gasoline: Automotive (4.23G PB/Gal)	GAT
443.	Gasoline: Aviation (4.86G PB/Gal)	GAV
444.	Gasoline: Casinghead	GCS
445.	Gasoline: Polymer	GPL
446.	Gasoline: Straight Run	GSR
447.	Gasoline Blending Stocks: Alkylates	GAK
448.	Gasoline Blending Stocks: Reformates	GRF
449.	Glutaraldehyde Solution	GTA
450.	Glycerine	GCR
451.	Glycidyl Methacrylate	GCM
452.	Glyoxal 40 (solution)	GOS
453.	Heptachlor	HTC
454.	Heptane	HPT
455.	Heptanol	HTN
456.	1-Heptene	HTE
457.	Hexachlorocyclopentadiene	HCC
458.	Hexadecyl Sulfate. Sodium Salt	HSS
459.	Hexadecyltrimethylammonium Chloride	HAC
460.	Hexaldehyde (N-)	HAL
461.	Hexamethylenediamine	HMD
462.	Hexamethyleneimine	HMI
463.	Hexamethylenetetramine	HMT
464.	Hexane	HXA
465.	Heptanol	HXN
466.	1-Hexene	HXE
467.	Hexylene Glycol	HXG
468.	Hydrazine	HDZ
469.	Hydrochloric Acid	HCL
470.	Hydrofluoric Acid	HFA
471.	Hydrogen. Liquified	HXX
472.	Hydrogen Bromide	HBR
473.	Hydrogen Chloride	HDC
474.	Hydrogen Cyanide	HCN
475.	Hydrogen Fluoride	HFX
476.	Hydrogen Peroxide	HPO
477.	Hydrogen Sulfide	HDS
478.	Hydroquinone	HDQ
479.	2-Hydroxyethyl Acrylate. Inhibited.	HAI
480.	Hydroxylamine Sulfate	HAS
481.	Hydroxypropyl Acrylate	HPA
482.	Hydroxypropyl Methacrylate	HPM
483.	Isoamyl Alcohol	IAA
484.	Isobutane	IBT
485.	Isobutyl Acetate	IBA
486.	Isobutyl Alcohol	IAL
487.	Isobutylamine	IAM
488.	Isobutylene	IBL
489.	Isobutyric Acid	IBR
490.	Isobutyronitrile	IBN
491.	Isodecaldehyde	IDA
492.	Isodecyl Acrylate. Inhibited	IAI
493.	Isodecyl Alcohol	ISA
494.	Isohexane	IHA
495.	Isoctaldehyde	IOC
496.	Isooctyl Alcohol	IOA
497.	Isopentane	IPT
498.	Isophorone	IPH
499.	Isophthalic Acide	IPL
500.	Isoprene	IPR
501.	Isopropyl Acetate	IAC
502.	Isopropyl Alcohol	IPA
503.	Isopropylamine	IPP
504.	Isopropyl Ether	IPE
505.	Isopropyl Mercaptan	IPM
506.	Isopropyl Percarbonate	IPC
507.	Isovaleraldehyde	IVA
508.	Jet Fuel: JP-1 (Kerosene)	JPO
509.	Jet Fuel: JP-3	JPT
510.	Jet Fuel: JP-4	JPF

CHRIS CHEMICALS (continued)

	Chemical Name	Chris Code		Chemical Name	Chris Code
511.	Jet Fuel: JP-5 (Kerosene, Heavy)	JPV	554.	Methyl Acetate	MTT
512.	Kerosene	KRS	555.	Methy Acetylene-Propadiene Mixture	MAP
513.	Lactic Acid	LTA	556.	Methylacrylate	MAM
514.	Latex. Liquid Synthetic	LLS	557.	Methyl Alcohol	MAL
515.	Lauroyl Peroxide	LPO	558.	Methylamine	MTA
516.	Lauryl Mercaptan	LRM	559.	Methyl Amyl Acetate	MAC
517.	Lead Acetate	LAC	560.	Methyl Amyl Alcohol	MAA
518.	Lead Arsenate	LAR	561.	Methylaniline (N-)	MAN
519.	Lead Fluoborate	LFB	562.	Methyl Bromide	MTB
520.	Lead Fluoride	LFR	563.	Methyl-N-Butyl Ketone	MBK
521.	Lead Iodide	LID	564.	Methyl Chloride	MTC
522.	Lead Nitrate	LNT	565.	Methyl Chloroformate	MCH
523.	Lead Tetraacetate	LTT	566.	Methylcyclopentadienylmonganese Tricarbonyl	MCT
524.	Lead Thiocyanate	LTC	567.	Methylcyclopentane	MCP
525.	Linear Alcohols (12-15 Carbons)	LAL	568.	Methyl Dichlorosilane	MCS
526.	Liquified Natural Gas	LNG	569.	Methyl Ethyl Ketone	MEK
527.	Liquified Petroleum Gas	LPG	570.	Methylethylpyridine	MEP
528.	Litharge	LTH	571.	Methyl Formal	MTF
529.	Lithium. Metal	LTM	572.	Methyl Formate	MFM
530.	Lithium Aluminum Hydride	LAH	573.	Methyl Hydrazine	MHZ
531.	Lithium Hydride	LHD	574.	Methyl Isobutyl Carbinol	MIC
532.	Magnesium	MGX	575.	Methyl Isobutyl Ketone	MIK
533.	Magnesium Perchlorate	MPC	576.	Methyl Isopropenyl Ketone. Inhibited	MPK
534.	Malathion	MLT	577.	Methyl Mercaptan	MMC
535.	Maleic Acid	MLI	578.	Methyl Methacrylate	MMM
536.	Maleic Anhydride	MLA	579.	Methyl Parathion	MPT
537.	Maleic Hydrazide	MLH	580.	Methylphosphonothioic Dichloride. Anhydrous	MPD
538.	Mercuric Acetate	MAT	581.	1-Methylpyrrolidone	MPY
539.	Mercuric Ammonium Chloride	MCC	582.	Methylstyrene. Alpha	MSR
540.	Mercuric Chloride	MRC	583.	Methyltrichlorosilane	MTS
541.	Mercuric Cyanide	MCN	584.	Methyl Vinyl Ketone	MVK
542.	Mercuric Iodide	MID	585.	Mineral Spirits	MNS
543.	Mercuric Nitrate	MNT	586.	Molybdic Trioxide	MTO
544.	Mercuric Oxide	MOX	587.	Monochloroacetic Acid	MCA
545.	Mercuric Sulfide	MSF	588.	Monochlorodifluoromethane	MCF
546.	Mercurous Chloride	MRR	589.	Monoethanolamine	MEA
547.	Mercurous Nitrate	MRN	590.	Monoisopropanolamine	MPA
548.	Mercury	MCR	591.	Morpholine	MPL
549.	Mesityl Oxide	MSO	592.	Motor Fuel Antiknock Compounds (Containing)	MFA
550.	Methallyl Chloride	MCL	593.	Nabam	NAB
551.	Methane	MTH	594.	Naphtha: Coal Tar	NCT
552.	Methanearsonic Acid. Sodium Salts	MSA	595.	Naphtha: Solvent	NSV
553.	Methoxychlor	MOC	596.	Naphtha: Stoddard Solvent	NSS

CHRIS CHEMICALS (continued)

Chemical Name	Chris Code	Chemical Name	Chris Code
597. Naphtha: VM + P (75 Naphtha)	NVM	644. Oil. Edible: Cotton-seed	OCS
598. Naphthalene. Molten	NTM	645. Oil. Edible: Fish	OFS
599. Naphthenic Acid	NTI	646. Oil. Edible: Lard	OLD
600. 1-Napthylamine	NAO	647. Oil. Edible: Olive	OOL
601. Neohexane	NHX	648. Oil. Edible: Palm	OPM
602. Nickel Acetate	NKA	649. Oil. Edible: Peanut	OPN
603. Nickel Ammonium Sul-fate	NAS	650. Oil. Edible: Saf-flower	OSF
604. Nickel Bromide	NBR	651. Oil. Edible: Soya Bean	OSB
605. Nickel Carbonyl	NKC	652. Oil. Edible: Tucum	OTC
606. Nickel Chloride	NCL	653. Oil. Edible: Vege-table	OVG
607. Nickel Cyanide	NCN	654. Oil. Fuel: No. 1 (Kerosene)	OON
608. Nickel Fluoborate	NFB	655. Oil. Fuel: No. 1-3	OOD
609. Nickel Formate	NFM	656. Oil. Fuel: No. 2	OTW
610. Nickel Nitrate	NNT	657. Oil. Fuel: No. 2-D	OTD
611. Nickel Sulfate	NKS	658. Oil. Fuel: No. 4	OFR
612. Nicotine	NIC	659. Oil. Fuel: No. 5	OFV
613. Nicotine Sulfate	NCS	660. Oil. Fuel: No. 6	OSX
614. Nitralin	NTL	661. Oil. Misc: Absorption	OAS
615. Nitric Acid	NAC	662. Oil. Misc: Coal Tar	OCT
616. Nitric Oxide	NTX	663. Oil. Misc: Croton	OCR
617. Nitrilotriacetic Acid and Salts	NAA	664. Oil. Misc: Linseed	OLS
618. 2-Nitrcaniline	NTA	665. Oil. Misc: Lubricat-ing	OLB
619. 4-Nitrcaniline	NAL	666. Oil. Misc: Mineral	OMN
620. Nitrobenzene	NTB	667. Oil. Misc. Mineral Seal	OMS
621. Nitroethane	NTE	668. Oil. Misc: Motor	OMT
622. Nitrogen. Liquified	NXX	669. Oil. Misc: Neatsfoot	ONF
623. Nitrogen Tetroxide	NOX	670. Oil. Misc: Penetrat-ing	OPT
624. Nitromethane	NMT	671. Oil. Misc: Range	ORG
625. 2-Nitrophenol	NTP	672. Oil. Misc: Resin	ORS
626. 4-Nitrophenol	NPH	673. Oil. Misc: Road	ORD
627. 2-Nitropropane	NPP	674. Oil. Misc: Rosin	ORN
628. Nitrosyl Chloride	NTC	675. Oil. Misc: Sperm	OSP
629. Nitrous Oxide	NTO	676. Oil. Misc: Spindle	OSD
630. Nonane	NAN	677. Oil. Misc: Spray	OSY
631. Nonanol	NNN	678. Oil. Misc: Tall	OTL
632. Nonene	NON	679. Oil. Misc: Tanners	OTN
633. 1-Nonene	NNE	680. Oil. Misc: Trans-former	OTF
634. Nonyl Phenol	NNP	681. Oil. Misc: Turbine	OTB
635. Octane	OAN	682. Oleic Acid	OLA
636. Octanol	OTA	683. Oleic Acid Potassium Salt	OAP
637. 1-Octene	OTE		
638. Octyl Epoy Tallate	OET		
639. Oil: Clarified	OCF		
640. Oil: Crude	OIL		
641. Oil: Diesel	ODS		
642. Oil. Edible: Castor	OCA		
643. Oil. Edible: Coconut	OCC		

CHRIS CHEMICALS (continued)

	Chemical Name	Chris Code
684.	Oleic Acid. Sodium Salt	OAC
685.	Oleum	OLM
686.	Oxalic Acid	OXA
687.	Oxygen. Liquid	OXY
688.	Paraformaldehyde	PFA
689.	Parathion	PTO
690.	Pentaborane	PTB
691.	Pentachlorophenol	PCP
692.	Pentadecanol	PDC
693.	Pentaerythritol	PET
694.	Pentane	PTA
695.	1-Pentene	PTE
696.	Peracetic Acid	PAA
697.	Perchloric Acid	PCL
698.	Perchloromethyl Mercaptan	PCM
699.	Petrolatum	PTL
700.	Petroleum Naphtha	PTN
701.	Phenol	PHN
702.	Phenyldichloroarsine. Liquid	PDL
703.	Phenylhydrazine Hydrochloride	PHH
704.	Phosgene	PHG
705.	Phosphoric Acid	PAC
706.	Phosphorus. Red	PPR
707.	Phosphorus. White	PPW
708.	Phosphorus Oxychloride	PPO
709.	Phosphorus Pentasulfide	PPP
710.	Phosphorus Tribromide	PDR
711.	Phosphorus Trichloride	PPT
712.	Phthalic Anhydride	PAN
713.	Piperazene	PPZ
714.	Polybutane	PLB
715.	Polychlorinated Biphenyls	PCB
716.	Polymethylene Polyphenyl Isocyanate	PPI
717.	Polyphosphoric Acid	PPA
718.	Polypropylene	PLP
719.	Polypropylene Glycol	PGC
720.	Polypropylene Glycol Methyl Ether	PGM
721.	Potassium	PTM
722.	Potassium Arsenate	PAS
723.	Potassium Binoxalate	PBO
724.	Potassium Chlorate	PCR
725.	Potassium Chromate	PCH
726.	Potassium Cyanide	PTC
727.	Potassium Dichloro-S-Triazinetrione	PDT
728.	Potassium Dichromate	PTD
729.	Potassium Hydroxide	PTH
730.	Potassium Iodide	PTI
731.	Potassium Oxalate	PTS
732.	Potassium Permanganate	PTP
733.	Potassium Peroxide	POP
734.	Propane	PRP
735.	Propiolactine. Beta	PLT
736.	Propionaldehyde	PAD
737.	Propionic Acid	PNA
738.	Propionic Anhydride	PAH
739.	Propyl Acetate (N-)	PAT
740.	Propyl Alcohol (N-)	PAL
741.	Propylene	PPL
742.	Propylene Butylene Polymer	PBP
743.	Propylene Glycol	PPG
744.	Propylene Glycol Methyl Ether	PME
745.	Propyleneimine. Inhibited	PII
746.	Propylene Oxide	POX
747.	Propylene Tetramer	PTT
748.	Propyl Mercaptan (N-)	PMN
749.	Pyridine	PRD
750.	Pyrogallic Acid	PGA
751.	Quinoline	QNL
752.	Rescrcinol	RSC
753.	Salicylic Acid	SLA
754.	Selenium Dioxide	SLD
755.	Selenium Trioxide	STO
756.	Silicon Tetrachloride	STC
757.	Silver Acetate	SVA
758.	Silver Carbonate	SVC
759.	Silver Fluoride	SVF
760.	Silver Iodate	SVI
761.	Silver Nitrate	SVN
762.	Silver Oxide	SVO
763.	Silver Sulfate	SVS
764.	Sodium. Metallic	SDU
765.	Sodium Alkylbenzenesulfonates	SAB
766.	Sodium Alkyl Sulfates	SAS
767.	Sodium Amide	SAM
768.	Sodium Arsenate	SDA
769.	Sodium Arsenite	SAR
770.	Sodium Azide	SAZ

CHRIS CHEMICALS (continued)

	Chemical Name	Chris Code		Chemical Name	Chris Code
771.	Sodium Bisulfite	SBS	817.	Tetraethylene Glycol	TTG
772.	Sodium Borate	SDB	818.	Tetraethylenepentamine	TTP
773.	Sodium Borohydride	SBH	819.	Tetraethyl Lead	TEL
774.	Sodium Cacodylate	SCD	820.	Tetraethyl Pyrophos-phate	TEP
775.	Sodium Chlorate	SDC	821.	Tetrafluoroethylene. Inhibited	TFE
776.	Sodium Chromate	SCH	822.	Tetrahydrofuran	THF
777.	Sodium Cyanide	SCN	823.	Tetrahydronaphthalene	THN
778.	Sodium Dichroromate	SCR	824.	Tetramethyl Lead	TML
779.	Sodium Dichloro-S-Triazinetrione	SDT	825.	Thiophosgene	TPG
780.	Sodium Ferrocyanide	SFC	826.	Thiram	THR
781.	Sodium Fluoride	SDF	827.	Thorium Nitrate	TRN
782.	Sodium Hydride	SDH	828.	Titanium Tetrachloride	TTT
783.	Sodium Hydrosulfide Solution	SHS	829.	Toluene	TOL
784.	Sodium Hydroxide	SHD	830.	Toluene 2.4-Diisocyan-ate	TDI
785.	Sodium Hypochorite	SHC	831.	Toluenesulfonic Acid (P-)	TAP
786.	Sodium Methylate	SML	832.	Toluidene (O-)	TLI
787.	Sodium Nitrite	SNT	833.	Toxaphene	TXP
788.	Sodium Oxalate	SOX	834.	Trichloroethane	TCE
789.	Sodium Phosphate	SPP	835.	Trichloroethylene	TCL
790.	Sodium Silicate	SSC	836.	Trichlorofluoromethane	TCF
791.	Sodium Silicofluoride	SFR	837.	Trichlorophenol	TPH
792.	Sodium Sulfide	SDS	838.	2.4.5-Trichlorophen-oxyacetic Acid	TCA
793.	Sodium Sulfite	SSF	839.	Trichlorosilane	TCS
794.	Sodium Thiocyanate	SCY	840.	Trichloro-S-Triazine-trione	TCT
795.	Sorbitol	SBT	841.	Tricresyl Phosphate	TCP
796.	Stearic Acid	SRA	842.	Tridecanol	TDN
797.	Styrene	STY	843.	1-Tridecene	TDC
798.	Sucrose	SRS	844.	Triethanolamine	TEA
799.	Sulfolane	SFL	845.	Triethylamine	TEN
800.	Sulfur (Liquid)	SXX	846.	Triethylbenzene	TEB
801.	Sulfur Dioxide	SFD	847.	Triethylene Glycol	TEG
802.	Sulfuric Acid	SFA	848.	Triethylenetetramine	TET
803.	Sulfuric Acid. Spent	SAC	849.	Triethylaluminum	TAL
804.	Sulfur Monochloride	SFM	850.	Trifluorochloroethylene	TFC
805.	Sulfuryl Chloride	SCL	851.	Trifluralin	TFR
806.	2.4.5 - T (Esters)	TES	852.	Triisobutylaluminum	TIA
807.	Tallow	TLO	853.	Trimethylamine	TMA
808.	Tallow Fatty Alcohol	TFA	854.	Trimethylchlorosilane	TMC
809.	Tannic Acid	TNA	855.	Tripropylene Glycol	TGC
810.	Tetrabutyl Titanate	TBT	856.	Tris(Aziridinyl)Phos-phine Oxide	TPO
811.	Tetrachloroethane	TEC	857.	Turpentine	TPT
812.	Tetrachloroethylene	TTE	858.	Undecanol	UND
813.	Tetradecanol	TTN			
814.	1-Tetradecene	TTD			
815.	Tetradecylbenzene	TDB			
816.	Tetraethyl Dithiopyro-phosphate	TED			

	Chemical Name	Chris Code
859.	1-Undecene	UDC
860.	Undecylbenzene (N-)	UDB
861.	Uranyl Acetate	URA
862.	Uranyl Nitrate	UAN
863.	Uranyl Sulfate	URS
864.	Urea	URE
865.	Urea Peroxide	UPO
866.	Valeraldehyde	VAL
867.	Vanadium Oxytrichlor-ide	VOT
868.	Vanadium Pentoxide	VOX
869.	Vanadyl Sulfate	VSF
870.	Vinyl Acetate	VAM
871.	Vinyl Chloride	VCM
872.	Vinyl Fluoride. Inhibited	VFI
873.	Vinylidenechloride. Inhibited	VCI
874.	Vinyl Methyl Ether. Inhibited	VME
875.	Vinyltoluene	VNT
876.	Vinyltrichlorosilane	VTS
877.	Wax: Carnauba	WCA
878.	Wax: Paraffin	WPF
879.	Xylene (N-)	XLM
880.	Xylene (O-)	XLO
881.	Xylene (P-)	XLP
882.	Xylenol	XYL
883.	Zinc Acetate	ZNA
884.	Zinc Ammonium Chloride	ZAC
885.	Zinc Arsenate	ZAR
886.	Zinc Borate	ZBO
887.	Zinc Bromide	ZBR
888.	Zinc Chloride	ZCL
889.	Zinc Chromate	ZCR
890.	Zinc Dialhyldithio-phosphate	ZDP
891.	Zinc Fluoborate	ZFB
892.	Zinc Nitrate	ZNT
893.	Zinc Phenolsulfonate	ZPS
894.	Zinc Phosphide	ZPP
895.	Zinc Silicofluoride	ZSL
896.	Zinc Sulfate	ZSF
897.	Zirconium Acetate	ZCA
898.	Zirconium Nitrate	ZIR
899.	Zirconium Oxychloride	ZCO
900.	Zirconium Sulfate	ZCS

APPENDIX D
EQUIPMENT LISTING

No.	Manufacturer	Model	Type of Unit
Liners			
101	American Colloid Co.	Volclay	Panel bentonite
102	Burke Rubber Co.	N/A	Pond liners
103	DuPont Co., Inc.	3110 Pond-Pit System Hypalon	Liners and covers
104	Fabrico Mfg. Corp.	N/A	Liners
105	Globe Linings, Inc.	Various	Liners
106	Gulf Seal Corp.	N/A	Liners
107	Hooker Chemical and Plastics Corp.	Hetron 197	Resin for chemical tanks
108	Liquid Containment Systems	N/A	Liners
109	Nalco Chemical Co.	N/A	Oil recovery with emulsion
110	Plasti-Steel Inc.	Reenforced Hypalon	Industrial liner
111	Plasti-Steel Inc.	2102	Vinyl industrial liner
112	Plymouth Rubber Co.	Plyliner/Hypalon	Liners
113	Soil Seal Corp.	N/A	Soil Seal concentrate (a soil stabilizer)
114	Staff Industries, Inc.	N/A	Liners
115	Techne Corp.	N/A	Euro-matic balls
116	United States Plastic Corp.	Various (catalog)	General plastics products, liners, etc.

APPENDIX D (continued)

No.	Manufacturer	Model	Type of Unit
	Liners (contd.)		
117	Watersaver Co.	Reenforced polyester	Liners
118	Wisconsin Plasite Coating Corp.	Various	Corrosion-resistant coatings
119	F.C. Witt Associates	N/A	Drop-in liners
	Pillow Tanks		
201	Aero Tech Labs, Ind.	120770 - Type H	Flexible tank
202	Kepner Plastics Fabricators, Inc.	---	Various size oil containment bags
203	William Wood and Associates for Dunlop Ltd.	Dracone Barge D10	Towable pillow tank
	Rigid Tanks		
301	Malony Crawford Corp.	---	Bolted bottom tanks up to 20,000 bbls capacity
302	Plasti-Steel, Inc.	---	Field-erect tanks up to 1,068,080 gal.
303	P&M, Inc.	---	Waste oil donuts
304	Tote Systems Division, Hoover Ball & Bearing Co.	A-110	Small container bulk handling system
305	American HCP, Inc.	Flatpack 90 Flatpack 146 Flatpack 180	Collapsible storage containers (90, 146, 180 gallon)

APPENDIX D (continued)

No.	Manufacturer	Model	Type of Unit
	Tractors (also, see ultimate disposal equipment)		
401	ATP, Inc.	Super Protractor Loader	All train tractor and loader w/various attachments
	Trucks		
501	Heil, Co.	Huge Haul Solid Waste System	Detachable truck containers
502	Industrial & Municipal Engineering Co.	S50-S-PB800-DE-NH	Vacuum module trailer
503	M-D Trailer Co.	Standard Vacuum Unit (Standard round exterior ring vacuum)	Transport tank
504	Super Products	Super Sucker	Industrial vacuum loader
505		Camel	Industrial vacuum loader
506	Central Engineering Corp.	Variety	Vac-All vacuum cleaners
507	Royal Vac	RTT & RTP	Vacuum tanks and pumps
508	Hayden Systems	Custom-to-order	Vacuum trucks
509	Myers Sherman	810 Vactor Jet Rodder	Vacuum truck
510	Knapheide Mfg. Co.	Numerous	Stake trucks
511	Galbreath, Inc.	A50D - 250T - HH U5010 - 182B - G U50D - 156B - HH and others	Roll-off container hauler
512	J B Systems, Inc.		Custom built tank trucks and trailers
513	Hobbs Trailers		Flat-bed trailer
514	Powerliner		Truck-tractor
515	Heil Co.		Huge Haul - roll-off bins

APPENDIX D (continued)

No.	Manufacturer	Model	Type of Unit
	Work Boats and Barges		
601	Acme Products Co.	The "Stallion" Model W-63 Work Boat	19' fiberglass Boston whaler
602	California Shipping and Drydock	the "Big Dipper"	Work boat w/hydraulic basket type scoop
603	Clean Water, Inc.	---	14' wooden work boat
604	U.S. Navy	Coyote	U.S. Navy Y.S.D. with converted bow
605	Stasch Marine Corp.	Drift Collector BD-6	Debris collecting barge
606	Murray & Tregurtha, Division of Mathewson Corp.	MV Port Service	Oil skimmer/work boat
607	Surface Separator Systems, Inc.	---	Debris Collector Craft (approx. 16')
608	Tacoma Boat Builders Co.	SWOBS	Waste off-loading barge
609	U.S. Navy	Racoon	Drift Collector
610	National Car Rental	MC 10	Dredging/Work Boat
611	National Car Rental	MC 15	Dredging/Work Boat
	Helicopters		
701	Bell Helicopter	The Biglifter - 214B	A 16-place single-engine turbine powered medium helicopter for utility and corporate use (Max. external load - 8,350 lbs.)

No.	Manufacturer	Model	Type of Unit
Cranes			
801	Barko Hydraulics, Inc.	160	Small truck-mount or stationary
802	Barko Hydraulics, Inc.	250	Articulated carrier or stationary (weight with loader = 33,000 lbs.)
803	Barko Hydraulics, Inc.	350	Articulated carrier or stationary (weight with loader = 48,000 lbs.)
804	Barko Hydraulics, Inc.	450	Crawler crane
805	Barko Hydraulics, Inc.	550	Crawler crane
806	Barko Hydraulics, Inc.	550	Carrier, or stationary (carrier weight = 88,000 lbs.)
807	Blaw-Knox Equipment, Inc.	TI-302	Incinerator grapple (weight = 7700 lbs.)
808	Crane Hoist Engineering Corp.	CH-904-080-06	1/2 ton cap. jib crane available w/single speed loadstar Model J hoist
809	Crane Hoist Engineering Corp.	CH-904-240-24	5 ton cap. jib crane available w/ loadstar hoist Model 5830
810	National Crane Co.	N-70	Truck mountable crane with bucket or other options (1 ton cap.)

APPENDIX D (continued)

No.	Manufacturer	Model	Type of Unit
	Conveyors		
901	Bucket Elevator Co.	Corra-Trough	Belt conveyors and conveyor elevators
902	J.W. Greer, Inc.	Gifford-Wood Z-bar Conveyor	Belt conveyor
903	Hapman Division/ Conveyor Corp.	---	Tubular conveyor
	Pumps		
1001	Acme Products, Inc.	FS-400	Floating saucer pump for liquids or sludges
1002	Agri-Lines Corp.	Parma No. 6	Multiservice submergible centrifugal
1003	Aurora Pump (a unit of General Signal)	663	Single stage vortex vertical pump
1004	Crisafulli Pump Co.	---	Trailer pumps (up to 24,000/gm) (may handle sludge)
1005	Crisafulli Pump Co.		Dredge pumps
1006	Flotec, Inc.	C8P8-3400V	Centrifugal pump

APPENDIX D (continued)

No.	Manufacturers	Model	Type of Unit
	Pumps (contd.)		
1007	Houdaille Pump Group	124 Series	Rotary pump
1008	Houdaille Pump Group	4124 Series	Rotary pump
1009	Kobe, Inc./ Baker International Corp.	Roto-Filter Pump	Rotary pump with vortex separation
1015	Waukesha Foundry Co., Inc.	3001 "I" Model	Rotary positive displacement pump
1016	Worthington	Open impeller self priming	Centrifugal pump
	Hoses and Connectors		
1101	Goodall Rubber Co.	N-147 "new-type" hose	Suction and discharge hose 8" dia. and couplings and other diameters
1102	Goodall Rubber Co.	Kemflex N-1689	Suction and discharge 4" dia. and other diameters
	Oil/Water Separators		
1201	Abcor, Inc.	N/A	Oil separators
1202	AFL Industries	F, F2, F3, B, B2, B3, and A3, GS-5	Gravity differential separator Separator, Polishing pack separator
1203	Alar Engineering Corp.	Pur-O-Lube 4	4 stage oil turbine purification system
1204	Allith Division Smith Jones, Inc.	Various	Liquid-liquid separators
1205	Bennett Pollution Controls	Sea Hawk	Oil/water separator
1206	Butterworth Systems, Inc.	N/A	Oil/water separator
1207	De Laval Separator Co.	N/A	Separators

APPENDIX D (continued)

No.	Manufacturer	Model	Type of Unit
	Oil/Water Separators (contd.)		
1208	Environetics, Inc.	N/A	Oil/water separators
1209	Envirosystems Corporation	N/A	Oil/water separators
1210	Enquip, Inc.	M-5, M-10	Oil/water separators
1211	Facet	N/A	Oil/water separator
1212	Foster Miller Assoc.	FMA	Pump type oil/water separator
1213	General Electric	OPL 25, 75 and 150	Oil/water separator
1214	Harco Mfg. Co.	HMC2 vertical HMC3 horizontal	Oil/water separators Oil/water separators
1215	Heil Process Equipment Co.	N/A	Corrugated plate separator
1216	Hycor Corporation	N/A	Oil/water
1217	Hyde Products, Inc.	1, 2, 3, 4, 12, 14, and 18	Oil/water separators
1218	ICI Pollution Control Systems	Flofoil	Oil/water separators
1219	Inland Environmental	Hydro-Gard C-22, 28, 35, 45, 70, 210, 240, 320 and 380	Oil/water separators
1220	Interdyne, Inc.	DYNA 1 and 2	Oil/water separators
1221	JBF Scientific Corporation	N/A	Oil recovery systems and vessels
1222	Korest-Peterson Co.	N/A	Oil/water separators
1223	Lockheed Missiles and Space Co. Inc.	R2002	Storage tank oil separator system

APPENDIX D (continued)

No.	Manufacturer	Model	Type of Unit
	Oil/Water Separators (contd.)		
1224	Mapco, Inc.	Series 1000, 1500 and 2000	Oil/water separator
1225	McTighe, Inc.	Portable Product Saver SK-PPS-1 Product Saver GD Product Saver MD	Oil/water separators
1226	Met-Pro Systems, Inc.	7023, 7018, 7024	Oil/water separators
1227	Metrol Corp.	Various	Separators
1228	Oil Mop Inc.	R-10, RC-50	Oil/water separator
1229	Orvalle Simpson Co.	Liquatex	Separators
1230	Pielkenroad Separator Co.	CFS	Oil/water separator
1231	Rex Chainbelt, Inc.	N/A	Float treat separators
1232	Seaward Internationsl, Inc.	Slurp	Adjustable Weir oil skimmer
1233	Surface Separator Systems, Inc.	---	Oil pollution control equipment
1234	United States Filter Corp.	Quadricell	Flotation separator
1235	Velcon Filters, Inc.	PM-1100-10-4 PM-1100-100-3A PM-1100-25-3 PM-1100-S-3 PM-1300 PM-1300-1 PM-1200	Oil/water separators
1236	Marco	RDS	Rotary drum separator

APPENDIX D (continued)

No.	Manufacturer	Model	Type of Unit
	Liquid/Solid Separators		
1301	Centri-Spray Corp.	Centri-Clerefier	Centrifugal liquid/solid separator
1302	Dorr-Oliver Corp.	C-250, C-400, C-600	Liquid/solid separator screen centrifuge
1303	Envirotech Corp.	144A WEMCO	Air floatation/separation depurator flotation machine
1304	Hycor Corp.	RSA 36120	Rotostrainer
1305	Laval Separator Corp.	SS0508-4	Two-stage centrifugal separator
1306	Rotex/ Division of the Orville Simpson Co.	L34-1	Screen-type liquid solids separator
1307	United States Filter Corp.	Q-500	Air floatation separator
1308	**Dravo**	**DJ Sinus Press**	**Sludge dewatering**
	Filters		
1401	Abcor, Inc.	---	Ultrafiltration membrane system for oil waste treatment
1402	Consler Corp.	---	Conventional pressure type filters

APPENDIX D (continued)

No.	Manufacturer	Model	Type of Unit
	Filters (contd.)		
1403	Harmsco, Inc.	HIF 200	Multi-cartridge industrial pressure filters
1404	Osmonics, Inc.	OSMO-6600-43-AB97B	Reverse osmosis recovery for oil, detergents, salts
1405	Romicon, Inc.	HF1S	Hollow fiber ultrafiltration system
1406	Saltech, Inc.	2160	Reverse osmosis applicable to dissolved inorganic solids
1407	Fluid Systems Div./ UOP, Inc.	N/A	Large-scale reverse osmosis treatment plants
1408	Union Carbide Corp.	---	Ultrafiltration reverse osmosis
1409	United States Filter Corp.	---	Conventional pressure filters
1410	Velcon Filters, Inc.	PM-1100-10-4C PM-1100-5-4C PM-1300-1 PM-1300	Filter-coalescer systems
	Chemical Treatment		
1501	Met-Pro Systems, Inc.	14007 14015 14025	Independent physical-chemical wastewater treatment systems for industry
1502		---	Phenol recovery plants

APPENDIX D (continued)

No.	Manufacturer	Model	Type of Unit
	Biological Treatment		
1601	Air Products & Chemicals, Inc.	OASES	Secondary wastewater treatment facility using O_2 for BOD removal, digestion, etc.
1602	Ralph B. Carter Co.	Static Mixaerator	Subsurface aeration w/ controlled air distribution
1603	Ecolotrol, Inc.	Hy-Flo	Fluidized bed wastewater treatment.
1604	FMC Corp.	---	Aerators, digesters, distributors
1605	Illinois Water Treatment Co.	---	De-ionizing system (activated carbon adsorbent) Triplex system
1606	Jet Aerator Co.	---	Packaged sewage treatment plant employing an extended aeration technique.
1607	Lakeside Equipment Corp.	Oxidation Ditch	Rotor (w/horiz. axis) in a ditch site shaped like a race-course (closed circuit)
1608	Sanilogical Corp.	---	Extended aeration by means of four (4) cyl. reactor vessels in a series/parallel arrangement.
1609	Zimpro, Inc.	---	Use of activated carbon as a system additive. Combines secondary and tertiary treatment steps into one.
1610	Union Carbide Corp.	UNOX	Secondary wastewater treatment facility using O_2 for BOD removal, digestion, etc.

APPENDIX D (continued)

No.	Manufacturer	Model	Type of Unit
	Shredders, Grinders, etc.		
1701	Allis-Chalmers, Inc.	KH10/7	Shredder
1702	Allis-Chalmers, Inc.	KH12/18	Shredder
1703	Allis-Chalmers, Inc.	KH16/24	Shredder
1704	Olathe Manufacturing Co.	816	Chipper
1705	Olathe Manufacturing Co.	300SF	Chipper
1706	Olathe Manufacturing Co.	172, 192, 130	Chippers
1707	Royer Foundry & Machine Co.	2600	Chipper
1708	Royer Foundry & Machine Co.	2640	Chipper
1709	Royer Foundry & Machine Co.	Woodsman 6000-P	Shredder
1710	Royer Foundry & Machine Co.	Woodsman 6000-D	Shredder
1711	Royer Foundry & Machine Co.	120, 182, 262, 363, 365	Belt shredders
1712	Strong Manufacturing Co.	Trelan C-14	Chipper
1713	Strong Manufacturing Co.	Trelan D-60	Chipper

APPENDIX D (continued)

No.	Manufacturer	Model	Type of Unit
	Incinerators		
1901	Basic Environmental Engineering, Inc.	4000	Incinerator w/afterburner
1902	Beloit-Passavant Corp.	N/A	Sludge de-watering and incineration system
1903	CEA Combustion, Inc.	N/A	Therman oxydizer - pulverized solids, liquids
1904	Combustion Engineering, Inc.	1, 3, 5, 7, 10 and 12	Rotary kiln incinerator w/afterburner
1905	Consumat Systems, Inc.	C-18, 32, 75, 120, 125, 225, 325, 550 and 760	Incineration systems
1906	Hauck Manufacturing Co.	WHG 112, 115, 120, 125, 130, 140, 1100 and 1120	Burners
1907	Hirt Combustion	LWHF	Liquid waste incinerator

APPENDIX D (continued)

No.	Manufacturer	Model	Type of Unit
	Incinerators (contd.)		
1908	Kelley Co., Inc.	N/A	Pyrolytic incinerator (on-site)
1909	W.S. Lagen	N/A	Not mfg. commercially, primary recycling incinerator
1910	Met-Pro Systems, Inc.	16030, 16060, 16090, 16120 and 16175	Rotary kiln incinerator w/afterburner
1911	Peabody Engineering	N/A	Liquid waste incinerator
1912	Progressive Equipment Co., Inc.	RC-01	Incineration systems
1913	Progressive Equipment Co., Inc.	RC-02	Incineration systems
1914	Schmidt Environmental Products, Inc.	SR100X1, 200X1, 300X1, 400X1, 500X1, SR800X1, 1000X1, 1250X1, 1500X1	Rectangular, general purpose incinerators
1915	Spronz Incinerator Corp.	RL-40	Class III Natural Draft Type w/primary and secondary combust. chamber
1916	Thermal Research and Engineering Corp.	6 VT, 15VT, 25VT, 3V, 7V, 10V, 14V, 18V, 24V, 30V, 48V	Liquid waste incinerators
1917	UE Corporation (Blue Flame Division)	B002, 005, 010, 030, and 090	Burners
1918	United Pacific Assoc., Inc. (PORTAPIT)	PORTAPIT 27	Open-top incinerator double-wall sides air-curtain combust.

APPENDIX D (continued)

No.	Manufacturer	Model	Type of Unit
	Incinerators (contd.)		
1919	Weiss Boilers (Frohnhausen, W. Ger.)	N/A	Wood-burning incinerator
1920	John Zink	N/A	Incinerator systems
1921	Otis		
1922	Sunbeam		
	Land Disposal Equipment		
2001	ATP, Inc.	Super Pro-Tractor	All-terrain loader/tractor
2002	Caterpillar Tractor Co.	910, 920, 930, 950, 966C, 980B, 988B	Wheel loaders
2003	Caterpillar Tractor Co.	931, 941B, 951C, 955L, 977L, 983	Track loaders
2004	Caterpillar Tractor Co.	816, 826B	Landfill compactors
2005	Caterpillar Tractor Co.	D3, D4D, D5, D6C, D7G, D8K, D9H	Track-type tractors

APPENDIX D (continued)

No.	Manufacturer	Model	Type of Unit
	Land Disposal Equipment (contd.)		
2006	Caterpillar Tractor Co.	613B, 613, 623B, 633D, 621B, 631D, 641B, 651B, 627B, 637D, 657B	Wheel tractor-scrapers
2007	Valmont Industries, Inc.	---	Sprinkler irrigation systems
2008	John Deere	JD 544-B & JD 644-B	Wheel loaders
2009	John Deere	JD: 570-A, 670, 770	Motor graders
2010	John Deere	JD 646-B	Landfill compactors
2011	John Deere	JD 750	Track dozer
2012	John Deere	JD 755	Track loader
2013	John Deere	JD 762 & JD 860-A	Scrapers
2014	Big Wheels, Inc.		Land spreading equipment
	Monitoring Equipment		
2101	Oil Recovery Systems, Inc.	---	Surface sampler
2102	Hyde Products, Inc.	OT3	Ultra violet fluorescence analysis of effluents
2103	Schonstedt Instrument Co.	GA-52	Magnetic locator
2104	Automation Products, Inc.	---	Dynatrol viscosity measuring device

APPENDIX D (continued)

No.	Manufacturer	Model	Type of Unit
	Protective Clothing		
2201	Bossman Co.	---	Protective jacket, vest, pants, helmet, chemical resistant boots, chemical resistant gloves
2202	Goodall Rubber Co.		Acid suit, gloves, goggles, workboots
2203	Army and Navy Contractors	POTMC (Army) PCS (Navy)	A complete body cover which is both liquid and vapor tight. Butyl rubber coverall with detachable boots, gloves, and a helmet. Air is also supplied for respiration and cooling.
	Portable Roadbeds, Bridges, Ramps, etc.		
2301	Kelley Company, Inc.	---	Recessed type docklevelers

APPENDIX D (continued)

No.	Manufacturer	Model	Type of Unit
Washing Equipment			
2401	Clayton Mfg. Co.	Steamin' Demon 100 Clean Master 180 Clean Master 300 HP-800 Hot High Pressure Washer Steamin' Demon 900	High pressure washers and steam cleaners
2402	Graco, Inc.	Hydra-Clean 1007	High pressure washer
2403	Oakite Products, Inc.	Hydro-Blitz 750	High pressure washer
Gas Handling System			
2501	Varec	Waste Gas Burner Fig. No. 239	Flaring device
2502	Varec	Vertical Fig. No. 50-91	Flame arrestor
2503	Paxton Products, Inc.	Compression Package Unit CB-60V	Blower

APPENDIX E

TRANSPORT AND DISPOSAL EQUIPMENT DIMENSIONS

(ALL DIMENSIONS IN METERS)

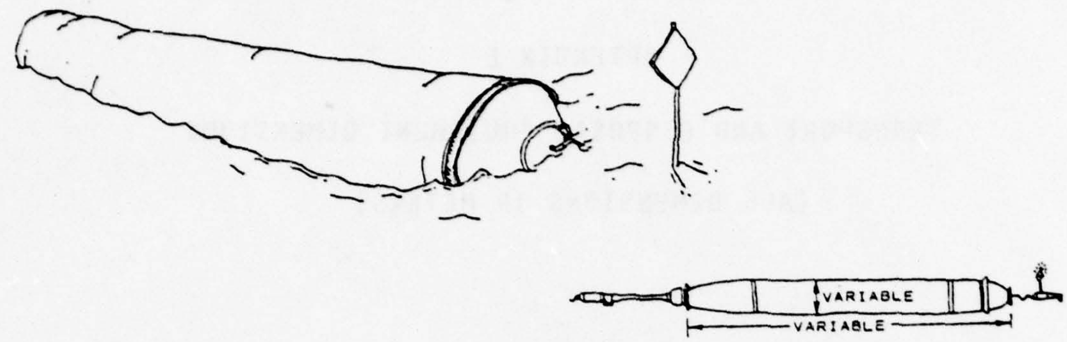


FIGURE E-1. ITEM 203: DRACONE BARGE D10.

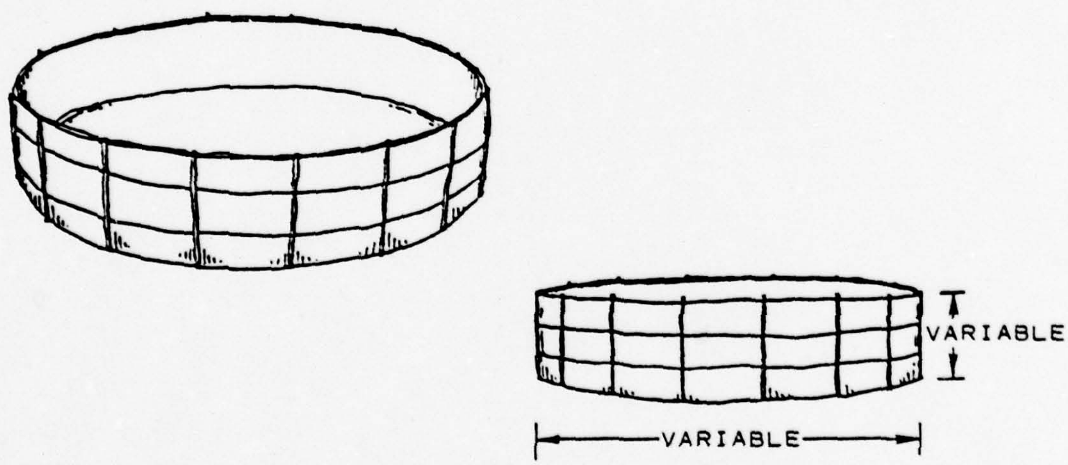


FIGURE E-2. ITEM 302: FIELD ERECT TANKS.

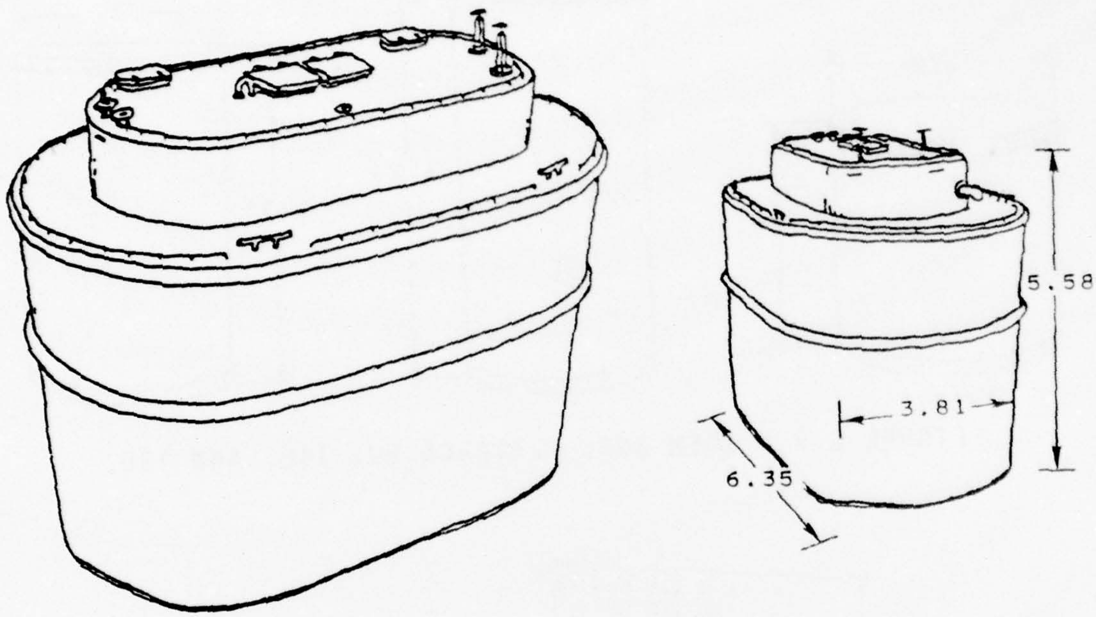


FIGURE E-3. ITEM 303: WASTE OIL DONUTS.

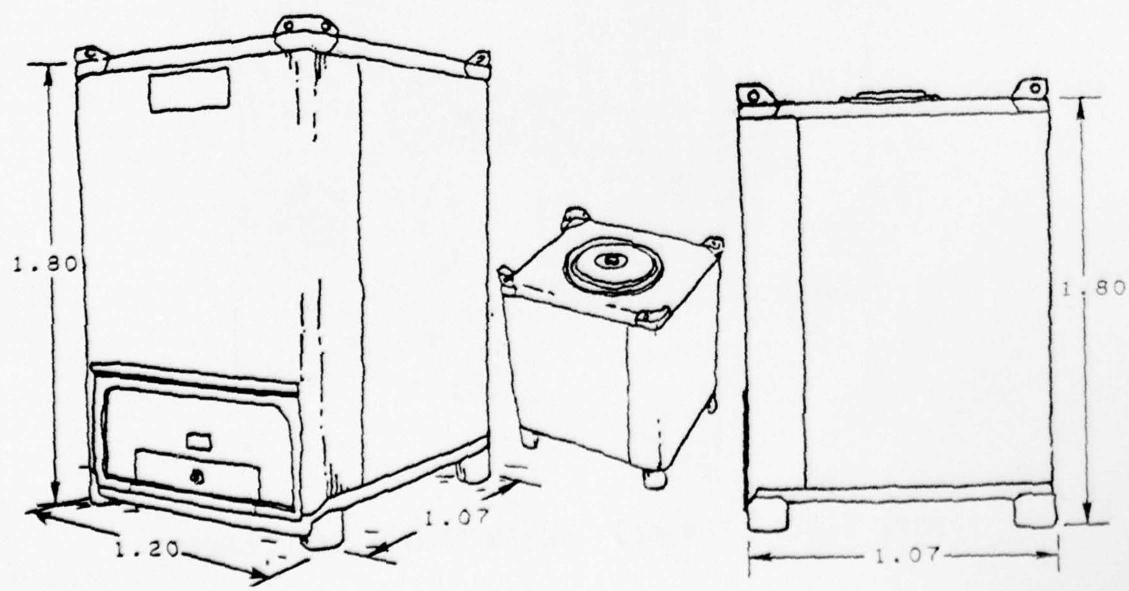


FIGURE E-4. ITEM 304: A110 SMALL CONTAINER BUCK HANDLING.

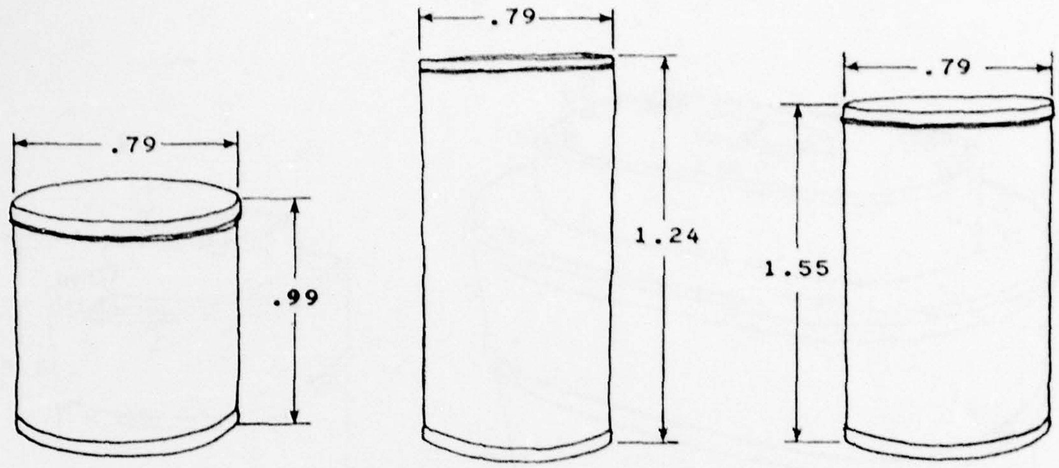


FIGURE E-5. ITEM 305: FLATPACK 90, 146, AND 180.

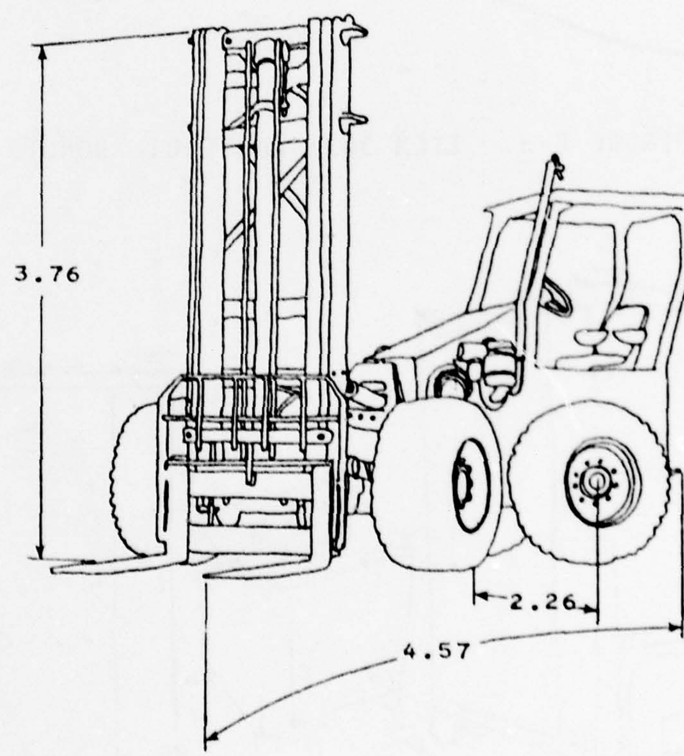


FIGURE E-6. ITEM 401: SUPER PROTRACTOR LOADER.

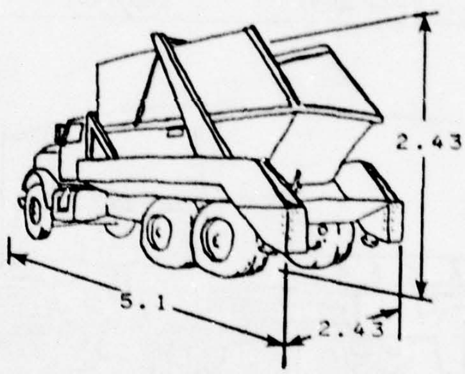


FIGURE E-7. ITEM 501: LOAD LUGGER SOLID WASTE SYSTEM.

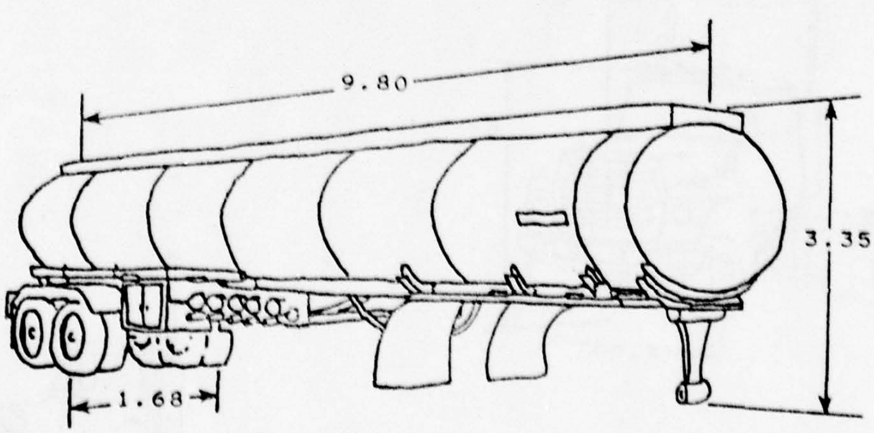


FIGURE E-8. ITEM 503: STANDARD VACUUM UNIT.

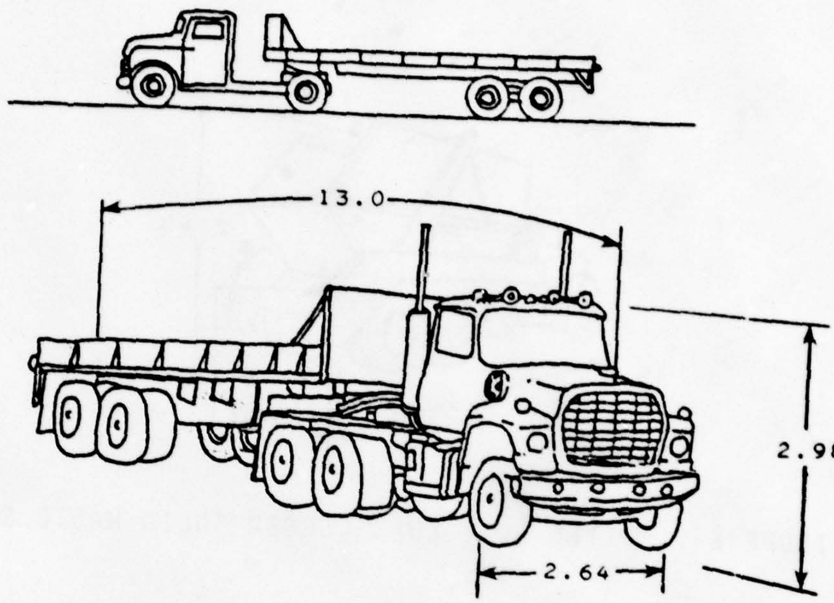


FIGURE E-9. ITEM 513: FLAT BED TRAILER.

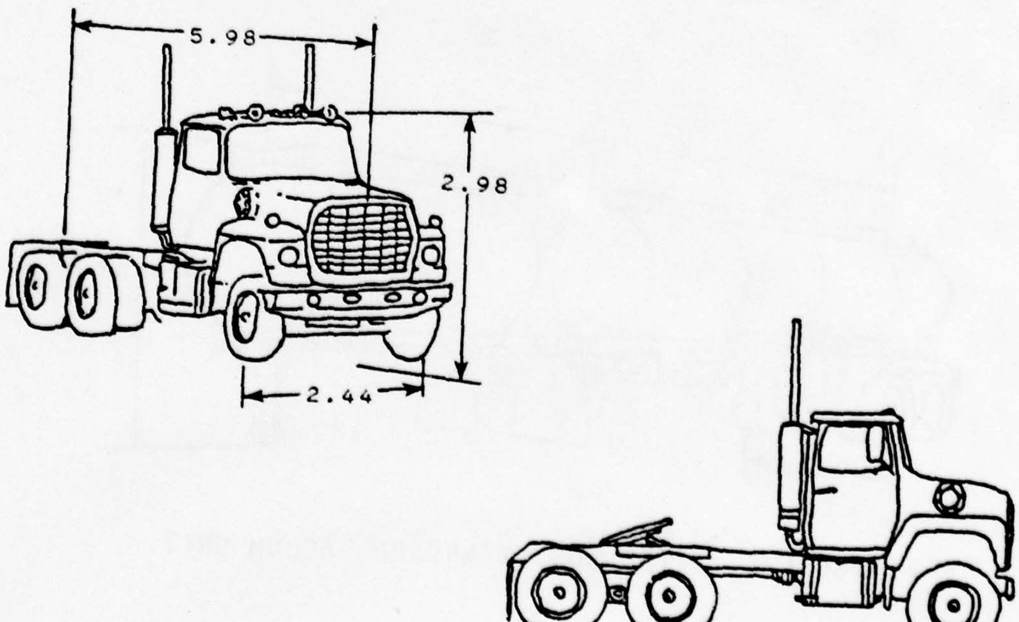


FIGURE E-10. ITEM 514: TRUCK TRACTOR.

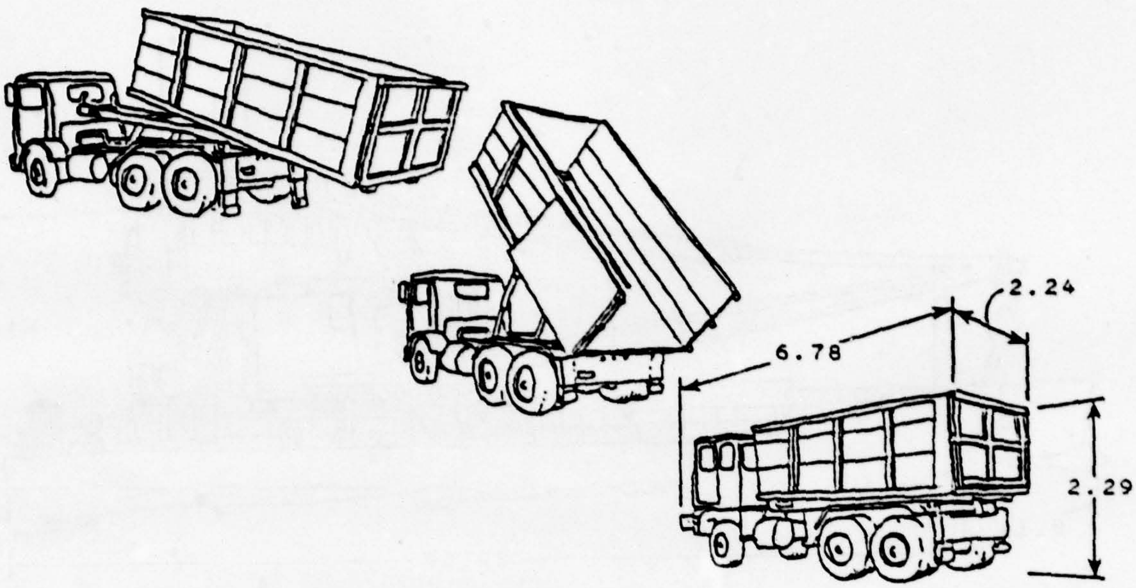


FIGURE E-11: ITEM 515: HUGE HAUL.

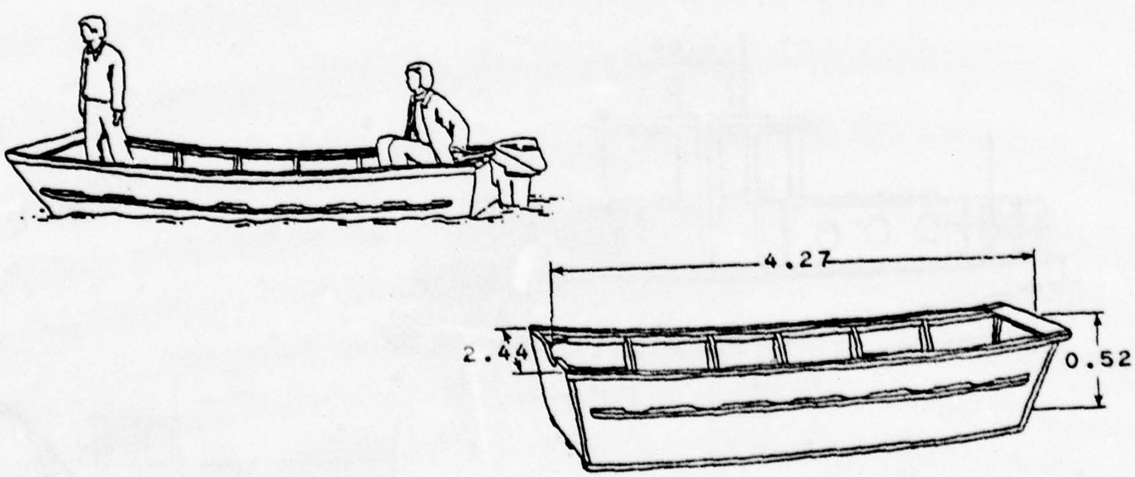


FIGURE E-12. ITEM 603: WORKBOAT.

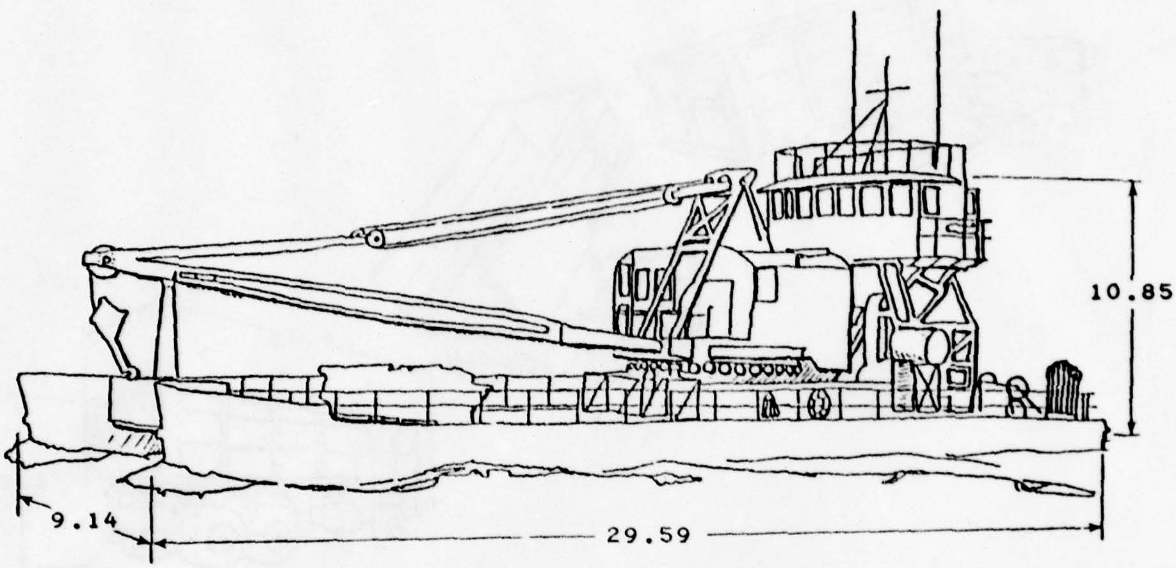


FIGURE E-13. ITEM 604: COYOTE.

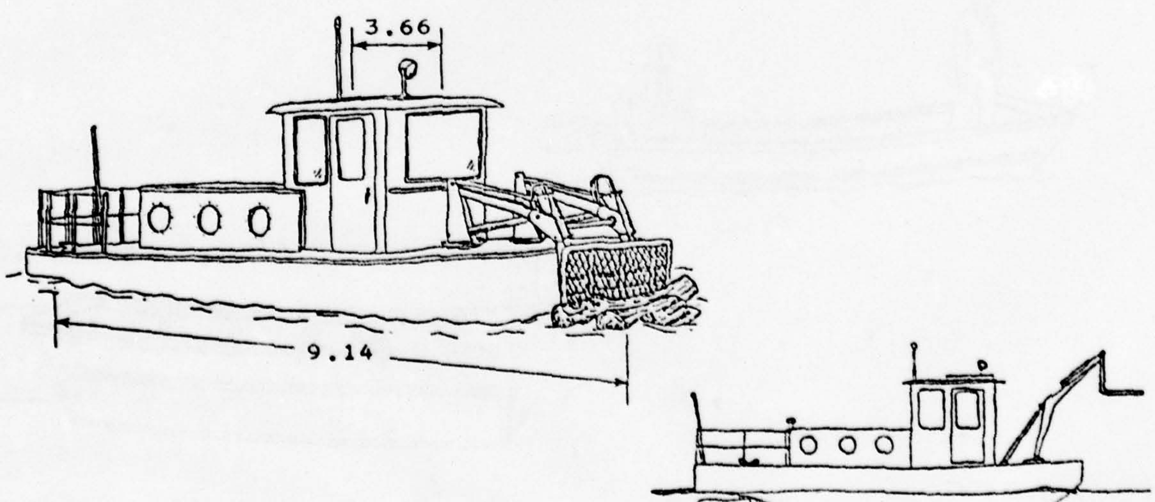


FIGURE E-14. ITEM 605: DRIFT COLLECTOR BO-6.

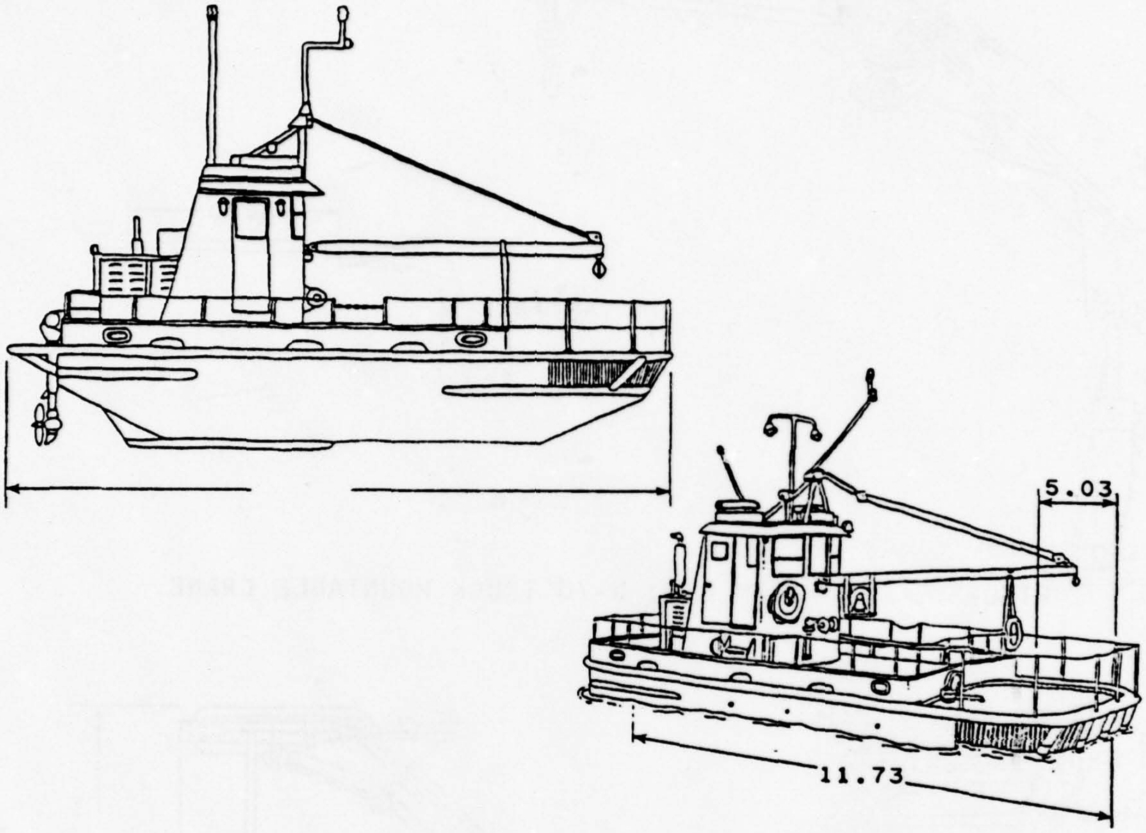


FIGURE E-15. ITEM 606: MV PORT SERVICE.

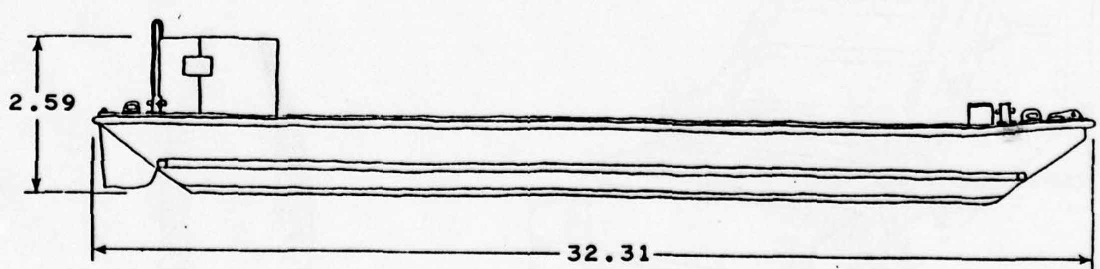


FIGURE E-16. ITEM 608: SOLID WASTE OFF-LOADING BARGE (SWOBS).

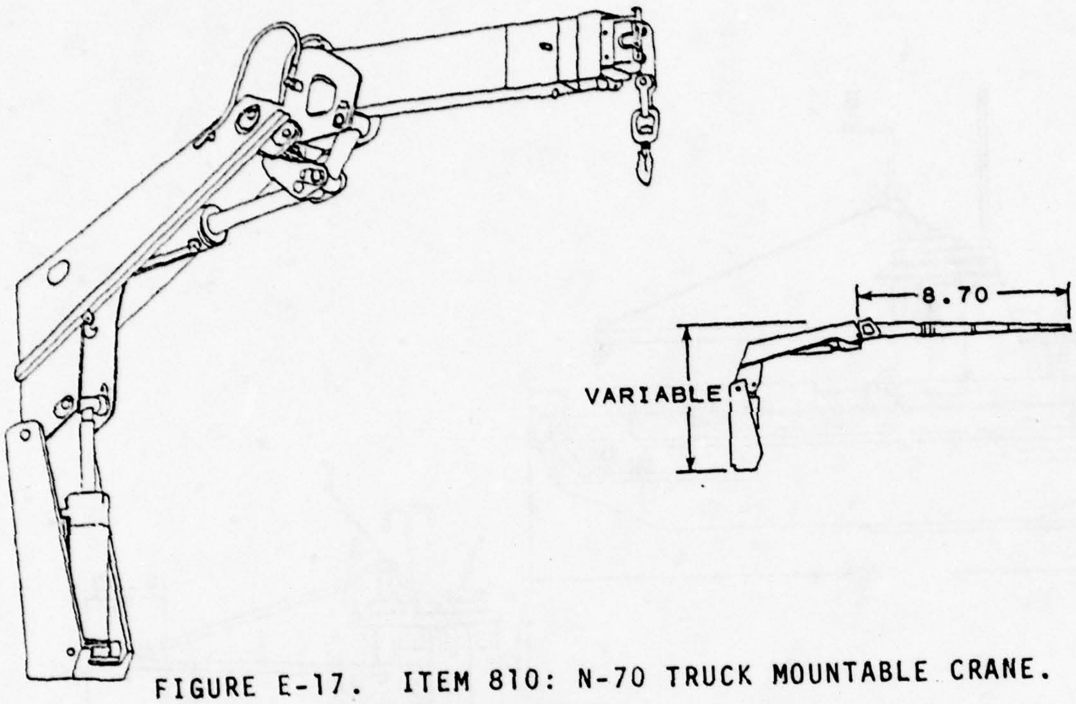


FIGURE E-17. ITEM 810: N-70 TRUCK MOUNTABLE CRANE.

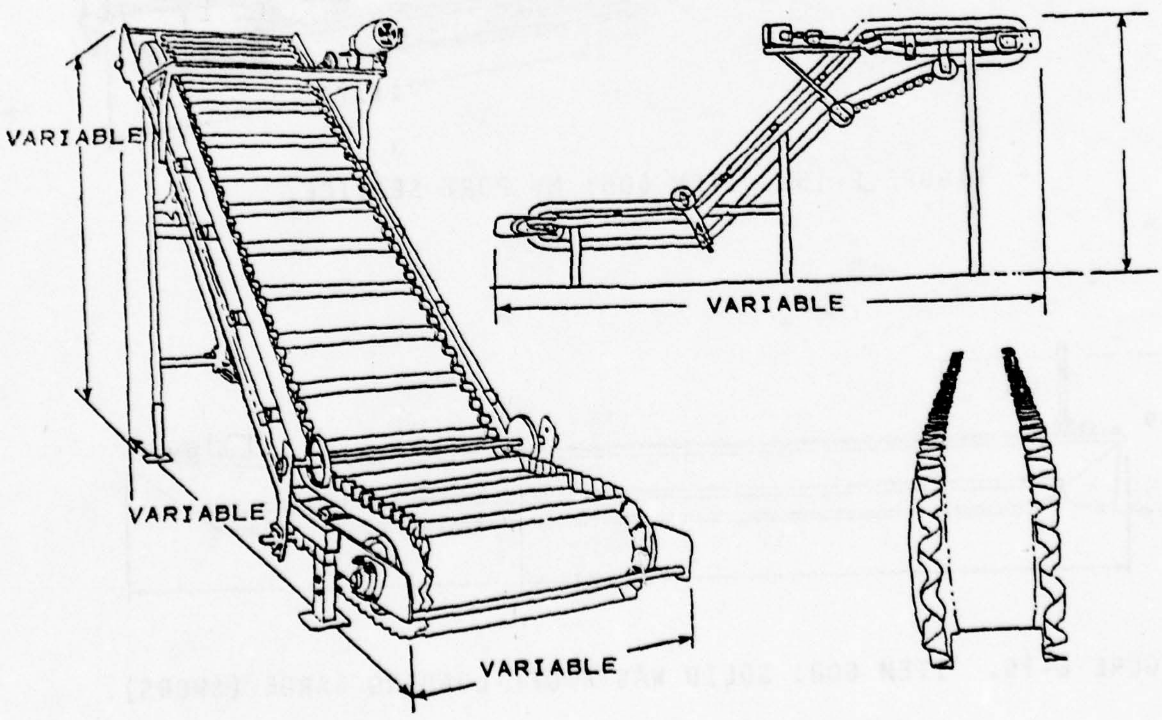


FIGURE E-18. ITEM 901: CORRA-TOUGH.

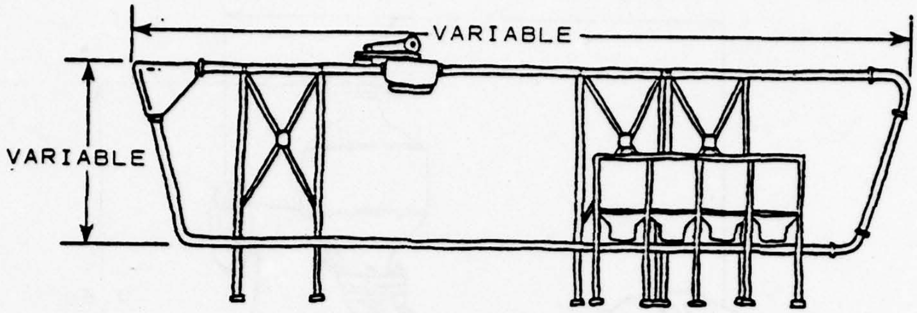


FIGURE E-19. ITEM 903: TUBULAR CONVEYOR.

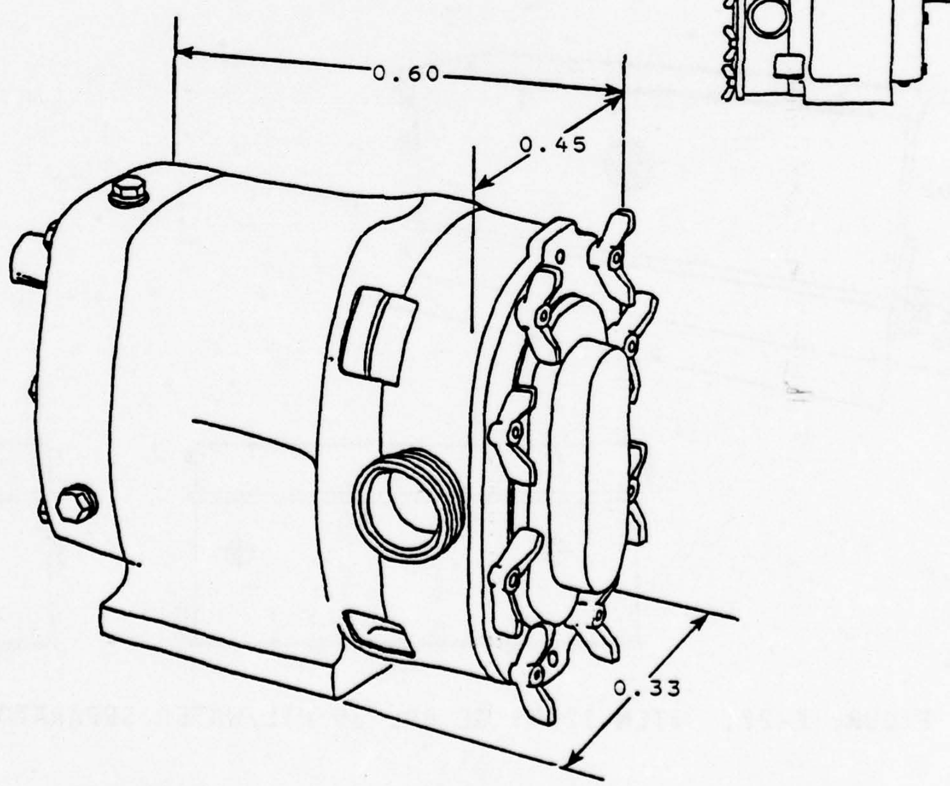


FIGURE E-20. ITEM 1015: MODEL 3001 I-SERIES.

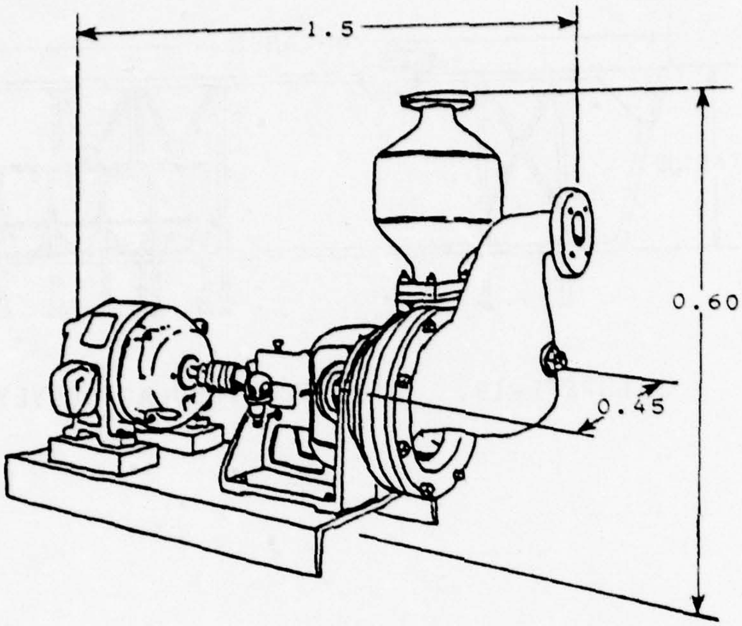


FIGURE E-21. ITEM 1016: SELF-PRIMING CENTRIFUGAL PUMP.

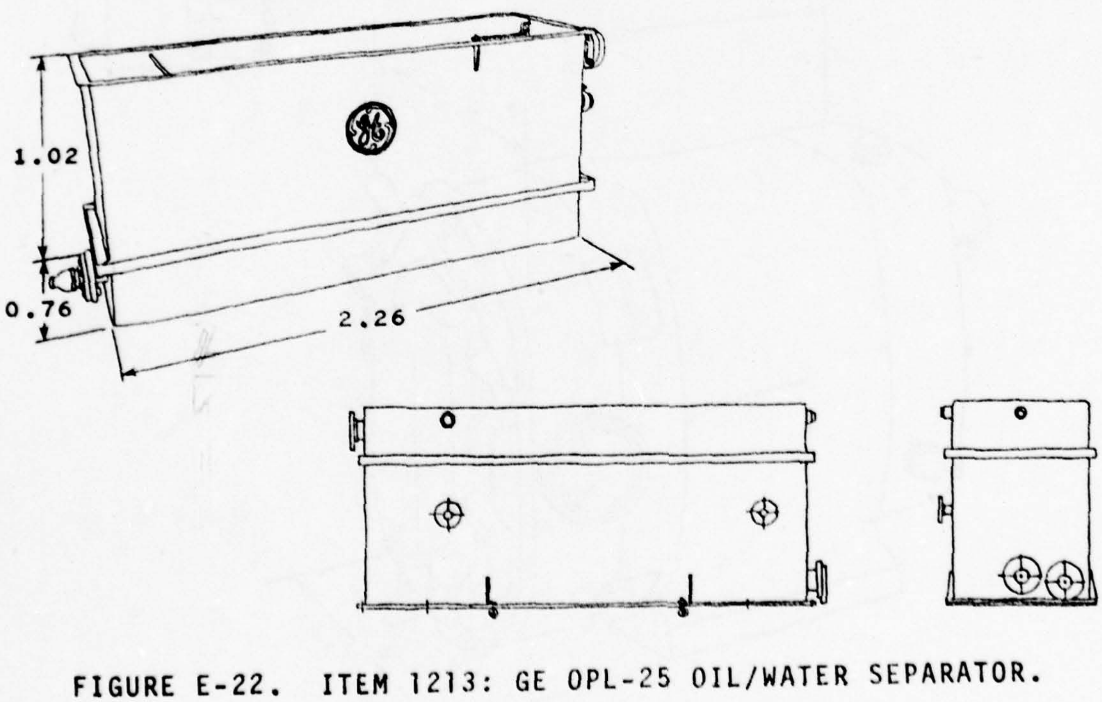


FIGURE E-22. ITEM 1213: GE OPL-25 OIL/WATER SEPARATOR.

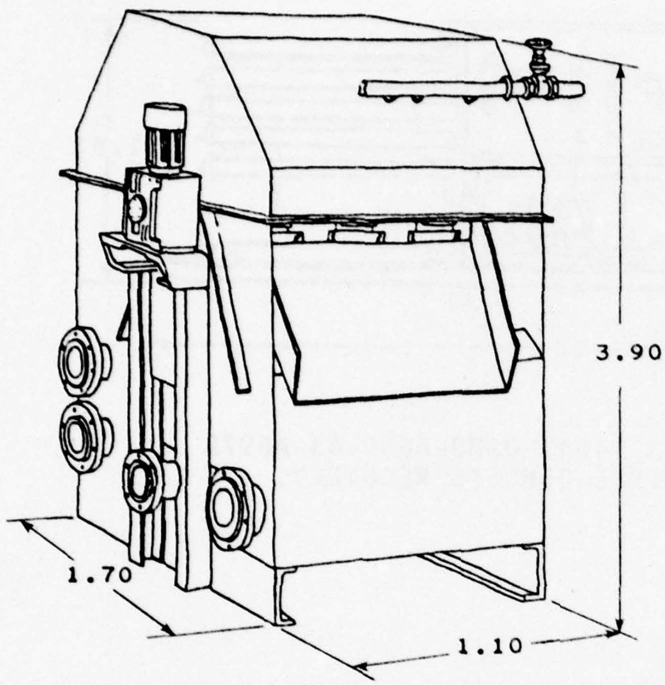


FIGURE E-23. ITEM 1304: RSA 36120 ROTOSTRAINER.

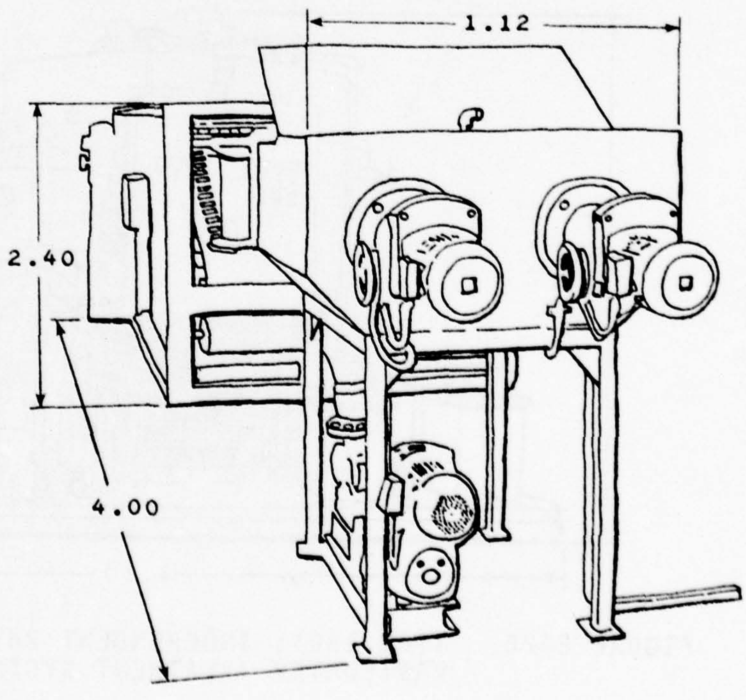


FIGURE E-24. ITEM 1308: D-J SINUS PRESS.

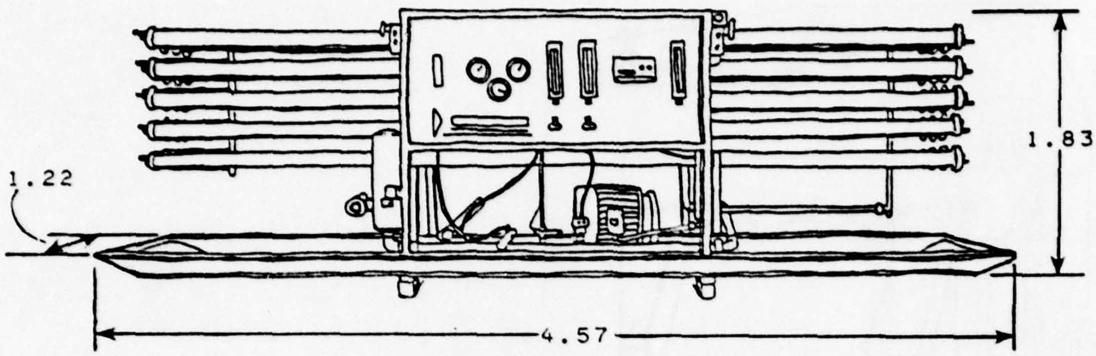


FIGURE E-25. ITEM 1404: OSMO-6600-43-AB97B REVERSE OSMOSIS RECOVERY.

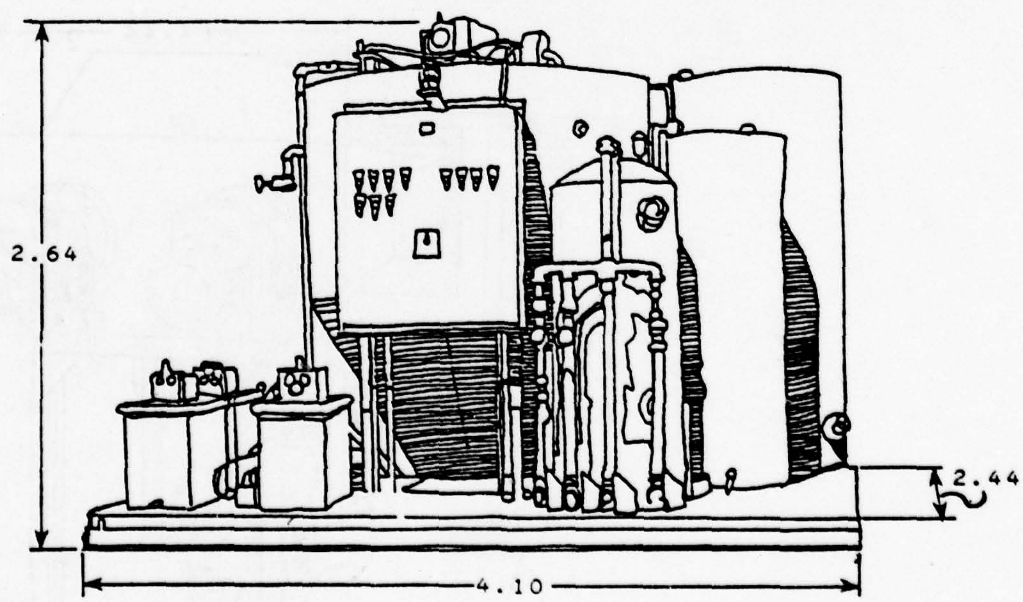


FIGURE E-26. ITEM 1501: INDEPENDENT PHYSICAL-CHEMICAL (IPC) WASTEWATER TREATMENT SYSTEM.

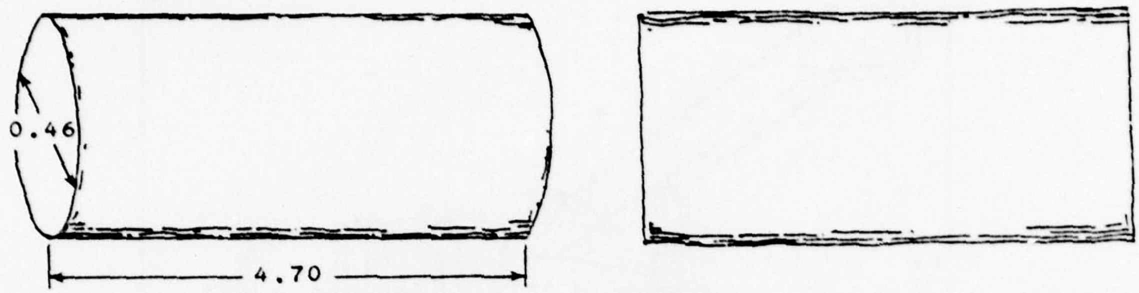


FIGURE E-27. ITEM 1603: HY-FLO FLUIDIZED BED WASTEWATER TREATMENT.

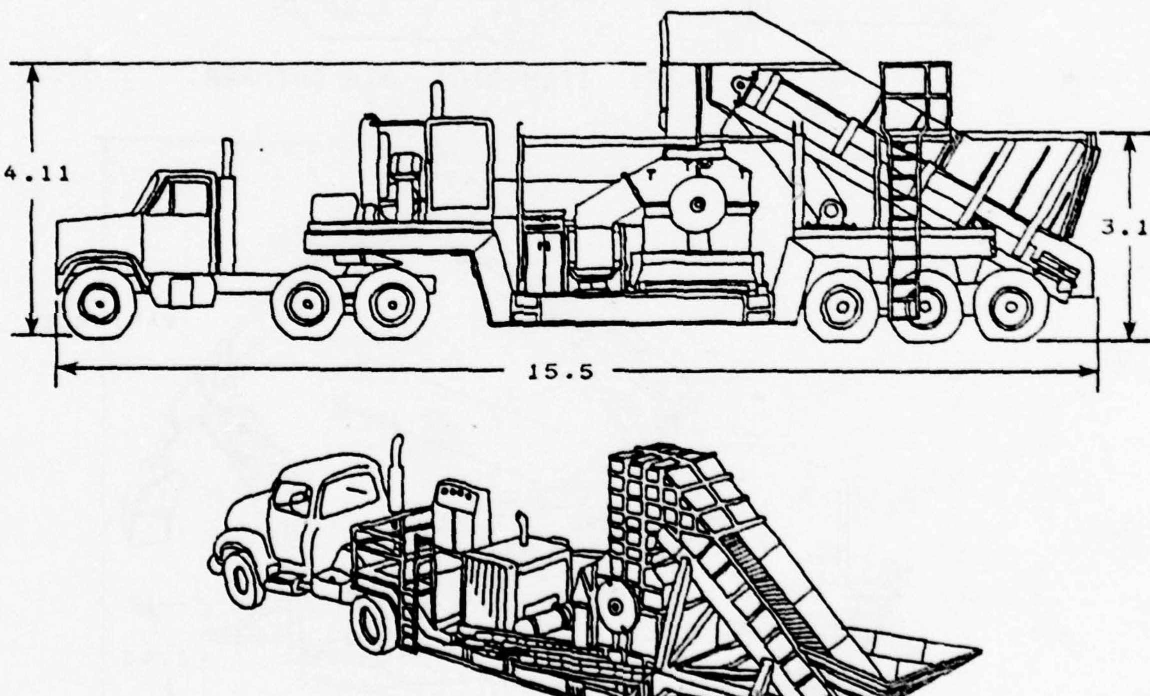


FIGURE E-28. ITEM 1701: KH10/7 SHREDDER.

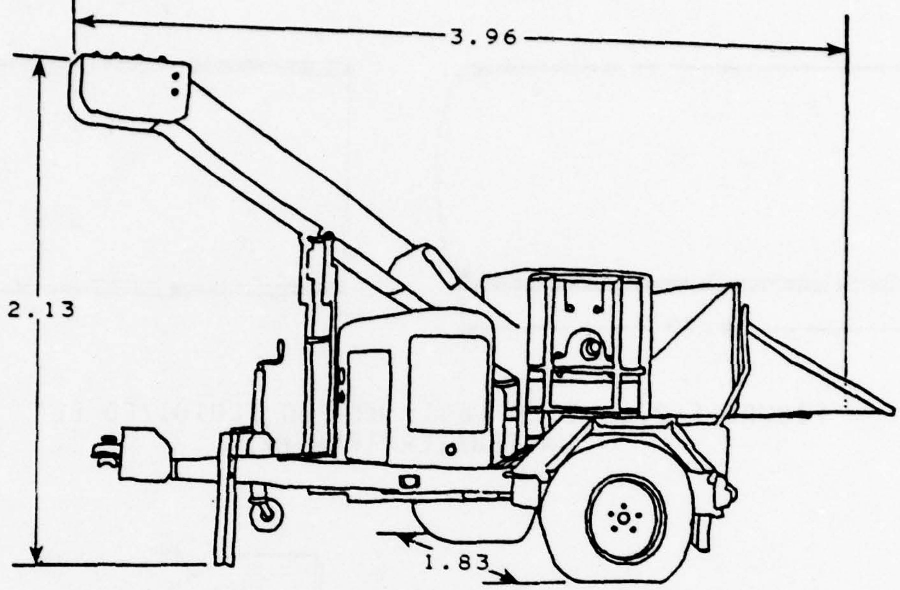


FIGURE E-29. ITEM 1704: 816 CHIPPER.

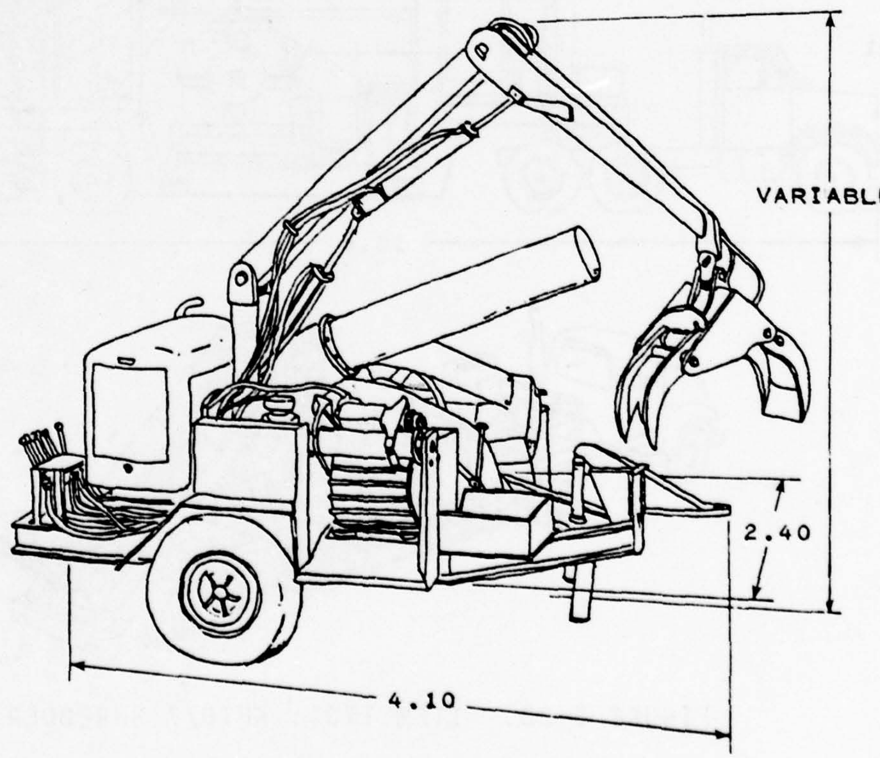


FIGURE E-30. ITEM 1712: TRELAN C-14 CHIPPER.

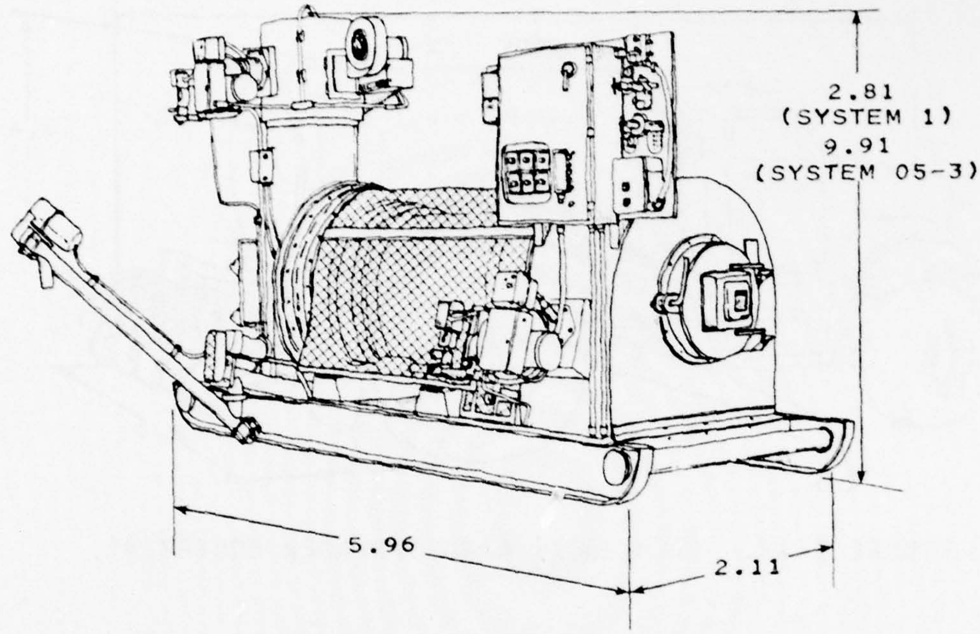


FIGURE E-31. ITEM 1910: INCINERATOR SYSTEM (HORIZONTAL)-MET-PRO.

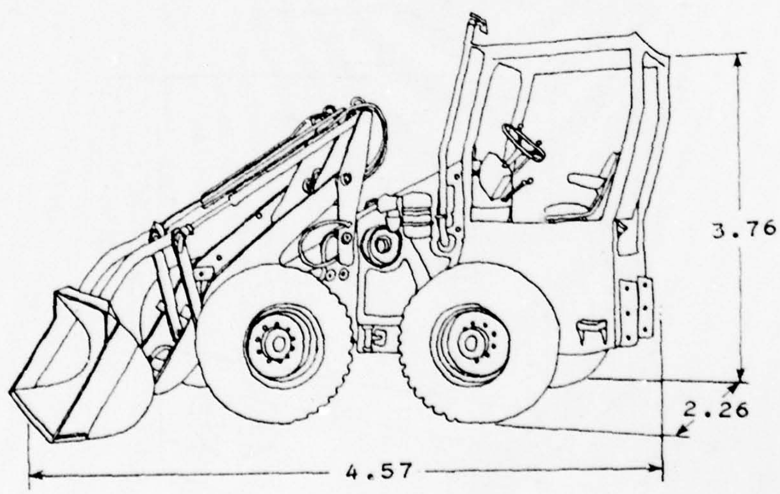


FIGURE E-32. ITEM 2001: SUPER PRO-TRACTOR.

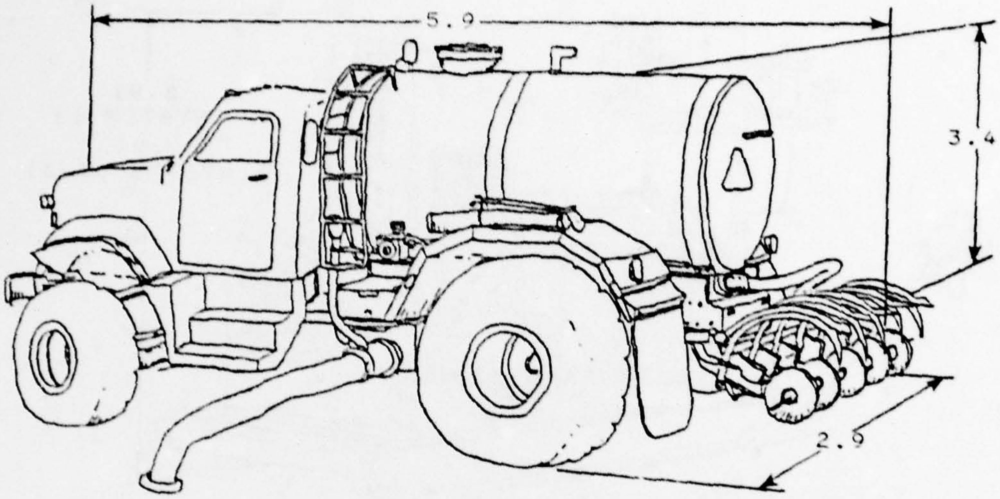


FIGURE E-33. ITEM 2014: LAND SPREADER EQUIPMENT.

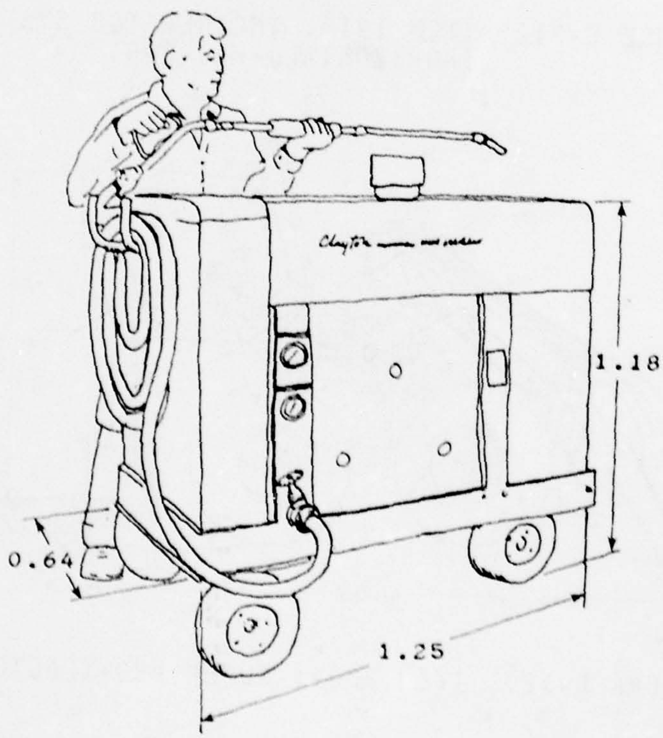


FIGURE E-34. ITEM 2401: HEAVY-DUTY STEAM CLEANER.

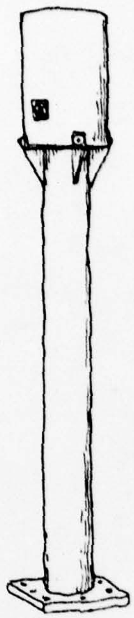


FIGURE E-35. ITEM 2501: FLARING DEVICE.

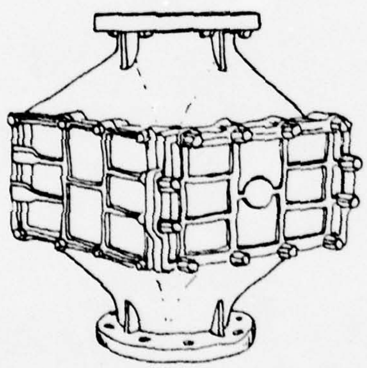


FIGURE E-36. ITEM 2502: FLAME ARRESTER.

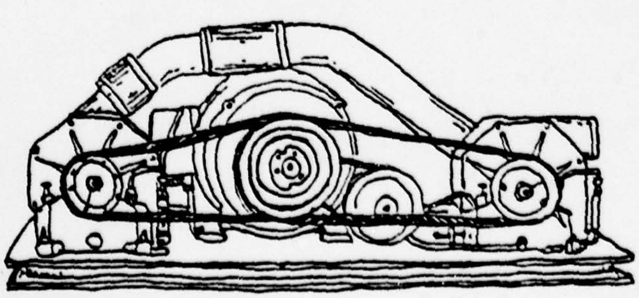


FIGURE E-37. ITEM 2503: BLOWER UNIT.

APPENDIX F

AIRCRAFT AND VESSELS AVAILABLE TO THE U.S. COAST GUARD: EQUIPMENT CARGO TRANSPORT CAPABILITIES

The Coast Guard's equipment, facilities, and operating procedures were examined to the extent that they physically interface with the oil disposal system. From these, a set of design requirements and goals were established and imposed on the engineering design evaluations of equipment.

Storage Ashore and Afloat

Coast Guard storage facilities ashore will be adequate for covered storage of the oil recovery system if the transport packages meet the following criteria:

- Designed to impose floor loadings of 2,400 kg/m^2 maximum (local code requirement specification)
- Fitted with tiedown, forklifting, and strapping capabilities
- Designed to deter pilferage
- Designed to allow access for preventive maintenance, such as pontoon servicing, machinery rotation, valve exercising, electrical checks, and periodic lubrication
- Void of requirements for external auxiliary services such as heat, lighting, or fluids.

Storage afloat requires that the system be packaged to withstand loading onto and into ships. For loading into certain Coast Guard Cutters, for instance, the package will undergo tilting loads. When stored below, provisions must be made for prior removal of hazardous materials from the components to satisfy Chapter 46 CFR.

Over-the-Road Transport

The 50 states regulate the sizes and weights of vehicles on highways within their borders. The oil recovery system packages must be sized to meet these limits. The lower limits for a three-axle semi or full trailer are 2.44 m wide, 4.11 m overall height, 12.19 m overall length (except 10.67 m in Wisconsin and

Oregon without permit), and 20.25 kkg gross for the load and vehicle. For combinations in excess of these limits, local permits may be required. In addition, package protection should be provided against missile hazards during transit.

Air Transport

A controlling design requirement is the air transport gross dimension and weight limits. These are defined in COMDT(FSP) letter dated October 15, 1971, file DOT-CG-14,057A. This requirement established maximum dimensions of 2.39 m width, 2.74 m height, and 12.19 m length, and a weight limit of 11.25 kkg.

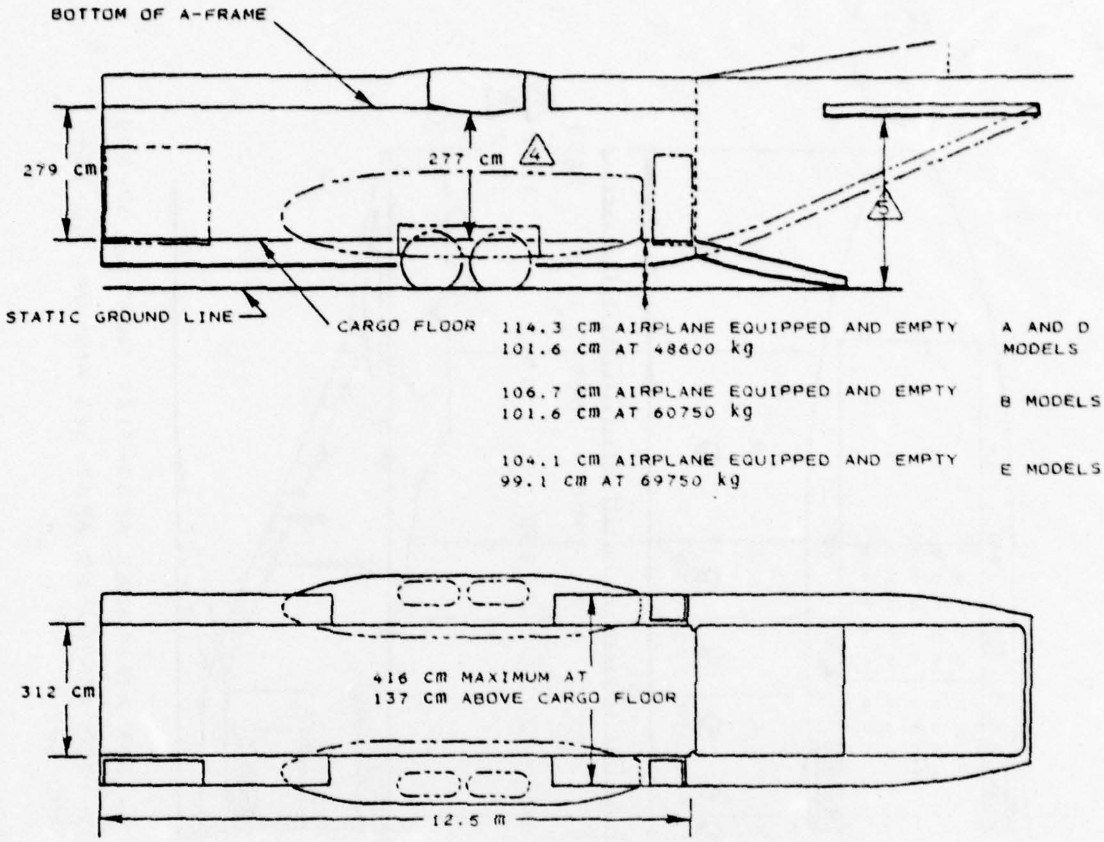
Other transport design goals provide for the use of the HC-130B cargo compartment and, when available, the cargo loading track system.

Certain significant restrictions appear in T.O. 1C-130A-9, dated 15 July 1970, covering the loading instructions for the aircraft. These restrictions apply to the selection of the package dimensions and weight. Restrictions are imposed on the loading of some cargo because of the crest of the opening at the junction of the lowered ramp and the cargo compartment floor.

The cargo winch capacity requires that flat-bottomed packages weighing more than 5,625 kg should not be skidded up the ramp unassisted. If the package weighs more than 3,825 kg, the angle formed by the cable passing around any snatch block is not to be less than 90 degrees. Loading aids in the form of auxiliary truck loading ramps, wheeled pry bars, and ramp supports are available.

The restrictions, coupled with the loading aids, control the design of packaging for the system. No jettisoning of the system packages is contemplated. In-flight inspection of the packaged load and the aircraft internals is required.

Pertinent cargo compartment characteristics of the HC-130B aircraft that affect the design of the system are presented in Figures F-1, F-2, and F-3.



NOTE

1 DIMENSIONS SHOWN ARE DISTANCES BETWEEN STRUCTURAL OR EQUIPMENT SURFACES.

2 SEE SHEET 2 FOR DETAILED DIMENSIONS.

3 PARATROOPERS JUMP FROM RAMP IF BUFFERS ARE INSTALLED.

4 2.74 m WITH LITTER BRACKET INSTALLED.

5 AIRPLANE ON HARD SURFACE, LANDING GEAR STRUTS AT STANDARD INFLATION, NOMINAL DIAMETER TIRES AT 35 PERCENT DEFLECTION. THIS DISTANCE IS:

C-130A: 3.71 m AT 48600 kg.CG AT 24.1% MAC.
C-130B: 3.73 m AT 60750 kg.CG AT 24% MAC.
C-130E: 3.63 m AT 69750 kg.CG AT 28.2% MAC.

6 BUFFER BOARD CLEARANCE

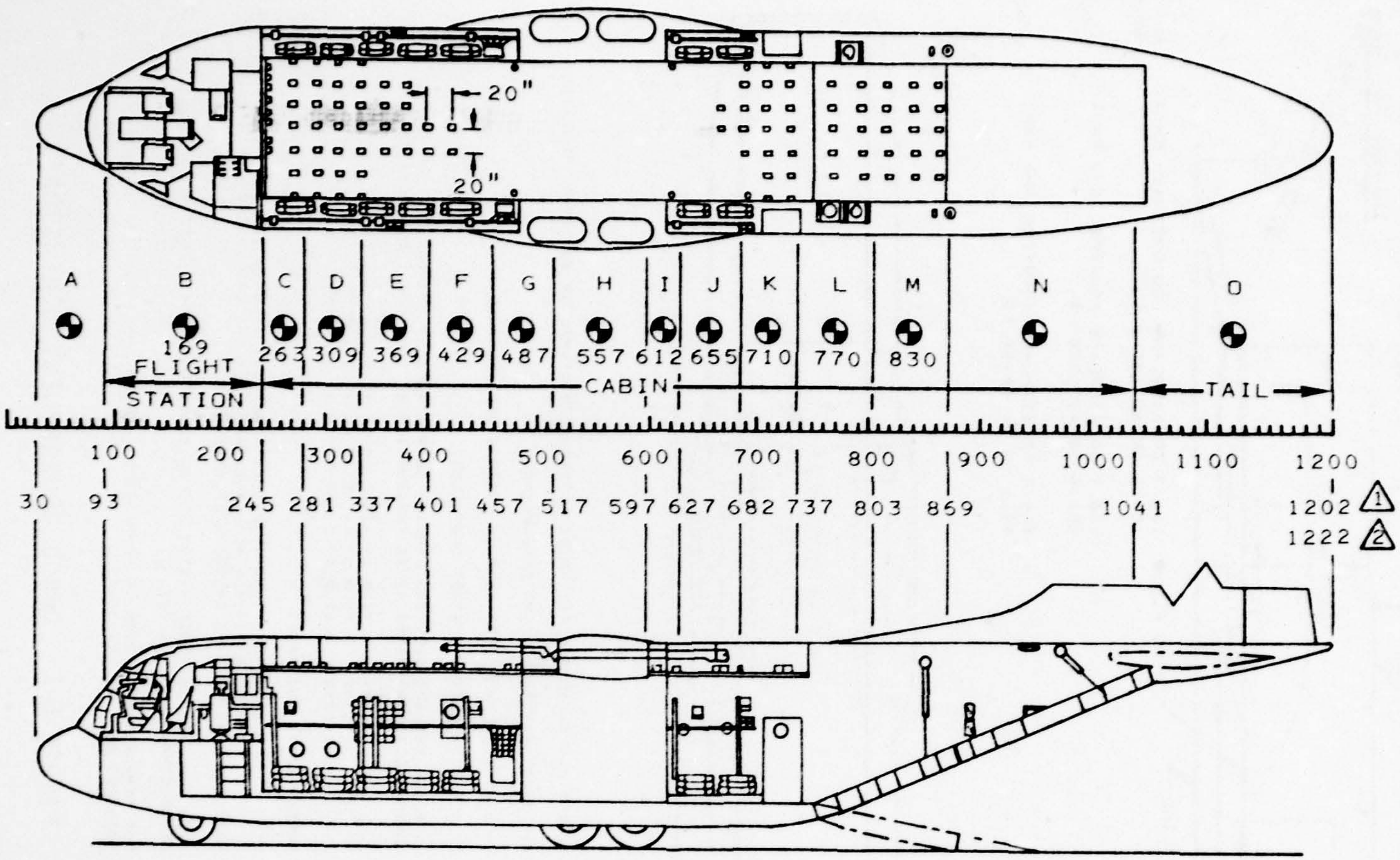
276.9 cm (C-130A AIRPLANES AF53-3129 THROUGH 56-509)
287.0 cm (C-130A AIRPLANES AF56-510 AND UP, C-130B, C-130D, AND C-130E AIRPLANES)

7 WITH DUAL RAIL AIRDROP SYSTEM INSTALLED DEDUCT 6.668 cm FROM CARGO COMPARTMENT HEIGHT.

8 THE FORWARD CARGO DOOR IS PERMANENTLY CLOSED ON AIRPLANES MODIFIED BY T.O. 1C-130-702.

FIGURE E-1. CARGO COMPARTMENT DIMENSIONS.

From: Beran, William T., Barrett Bruch, and Kenneth R. Maxwell, A Prototype High Seas Oil Recovery System, *Phase I - System Development*, Lockheed Missiles and Space Company, Inc., February 1972. Vol. I, P. 2-14.



NOTE

THE LAST ELEVEN INCHES OF COMPARTMENT M IS NOT FLOOR SPACE.

1 C-130A AIRPLANES AF53-3129 THROUGH 57-509.

2 C-130B AIRPLANES AF57-525 AND UP; CG-1339 AND UP.

FIGURE F-2. CARGO COMPARTMENTS.

From: Ibid., page 2-15.

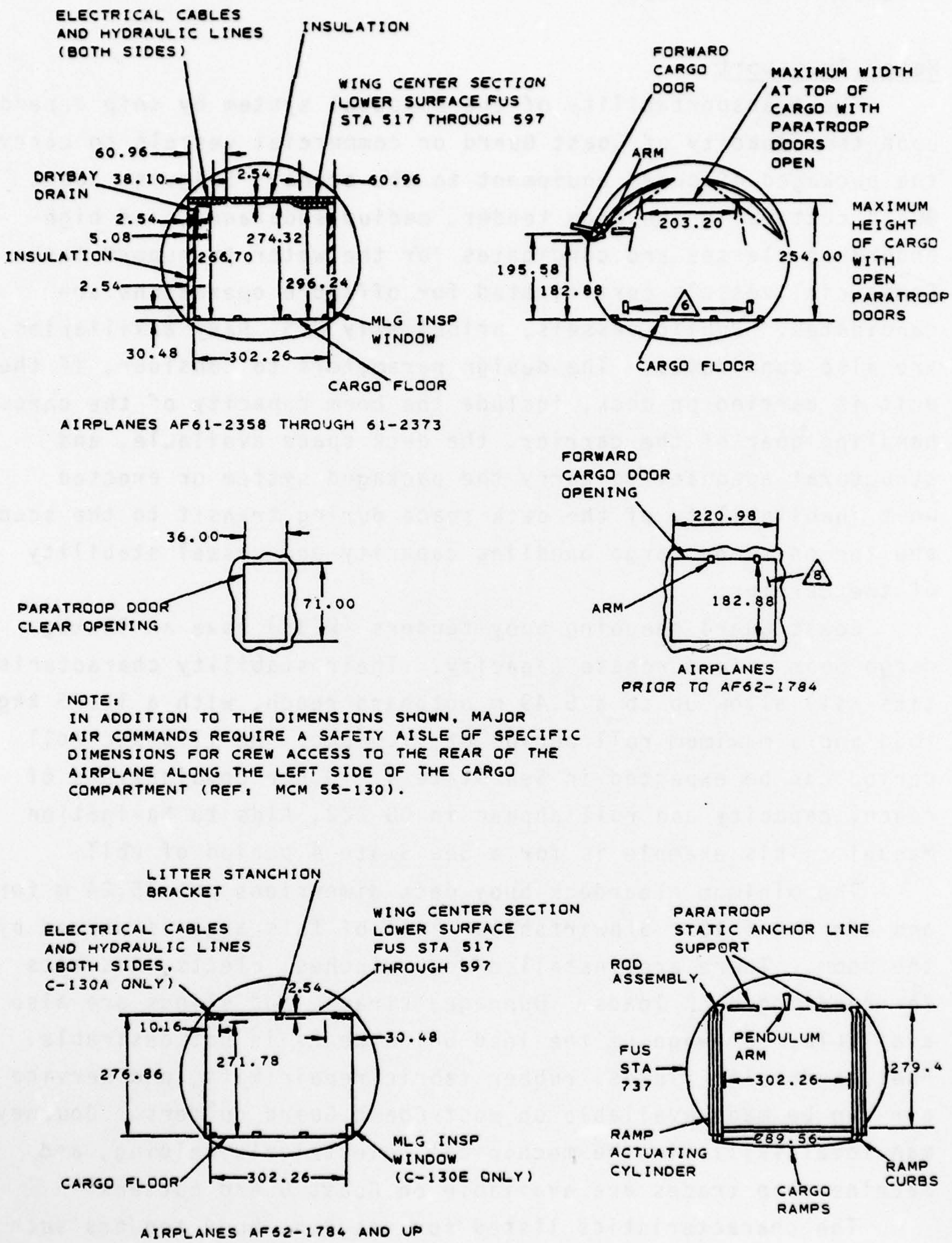


FIGURE F-3. C130 TRANSPORT CARGO CAPACITY.

From: Ibid., page 2-16.

Water Transport

The transportability of the disposal system by ship depends upon the capacity of Coast Guard or commercial vessels to carry the packaged disposal equipment to the scene. Seagoing Coast Guard cutters in the buoy tender, medium-endurance, and high-endurance classes are candidates for the water transport task. Commercial vessels certificated for offshore operations are candidates. Public vessels, principally U.S. Navy auxiliaries, are also candidates. The design parameters to consider, if the unit is carried on deck, include the boom capacity of the cargo handling gear of the carrier, the deck space available, and structural adequacy to carry the packaged system or erected unit, habitability of the deck space during transit to the scene, and the on-scene cargo handling capacity and vessel stability of the carrier.

Coast Guard seagoing buoy tenders (WLBs) have an 18-kkg cargo boom main purchase capacity. Their stability characteristics will allow up to a 5.49 m outboard reach, with a 11.25 kkg load and a maximum roll period of 11.5 sec. An 11.5-sec roll period can be expected in Sea State 4. Other combinations of reach, capacity and roll appear in CG-222, Aids to Navigation Manual. This example is for a Sea State 4 period of roll.

The minimum cleardeck buoy deck dimensions are 15.24 m fore and aft and 6.10 m athwartships. All of this area is served by the boom. There are installed deck winches, cleats, and bits for handling deck loads. Dunnage, straps, and slings are also available. Stowage of the load below decks is not desirable. Fuel, hydraulic fluids, rubber fabric repair kits, and service air can be made available on most Coast Guard cutters. Journeyman level skills in the mechanical, electrical, welding, and machine shop trades are available on Coast Guard cutters.

The characteristics listed for seagoing buoy tenders such as boom capacity and deck space serviced by the boom are also identified as the minimum required of commercial and public

vessels to deliver the disposal system. If towing is considered, the system design parameters must include the limiting bollard pulls of Coast Guard buoy tenders and cutters. These are 12.15 kkg for the inland buoy tender, 12.6 kkg for the 55-m class of seagoing buoy tenders, 31.5 kkg for the 64-m medium-endurance cutter, and 58.5 kkg for the 115-m high-endurance cutter.

Cargo boom capacities on certain other Coast Guard cutters are comparable to or less than that of the seagoing buoy tender class. When boom capacity is comparable, however, other limitations exist. In most cases, deck space is at a premium. Exceptions are two cargo vessels and a single vessel class icebreaker (CGC STORIS), all of which have both boom capacity and deck space to transport disposal equipment systems of the dimensions listed under the air transport subsection of this report.

Towable Planing Hull Sleds

The Coast Guard is presently developing various rapid surface transport systems to deliver the pollution control equipment to the scene of an oil spill. A towed planing hull sled is one such approach to a fast surface delivery system characterized by low investment cost, simplicity in design, and good delivery capability.

A proposal to develop a planing hull sled for the FSD system was submitted to the Coast Guard by the Naval Coastal Systems Laboratory. After consideration of the proposal, the Coast Guard issued a Military Interdepartmental Purchase Request (MIPR) to NCSL to perform the work. The units can be used to deliver two ADAPTS Systems, one High Seas Oil Containment Barrier, or one Oil Recovery Device:

1. ADAPTS System (Air Deliverable Antipollution Transfer System). Two packages: A. Pump package - 4,740 lb, and B. Bag package - 6,250 lb.

APPENDIX F (continued)

2. High Seas Oil Recovery Device (Oil Recovery System built for the Coast Guard by Lockheed Corporation). Total weight - 16,000 lb.

3. Barrier (High Seas Containment Barrier). Total weight - 17,000 lb.

Planing hull sleds are to be located at strategic Coast Guard Stations. In the event of an oil spill or other marine disaster requiring use of pollution control equipment, the sled, loaded with appropriate equipment, will be towed by surface craft or helicopter to the site of the disaster and unloaded. The empty sled can be towed back to port for reloading with other equipment, if required. It is assumed that the sled can accommodate disposal system equipment, similar in dimensions and weight to the barriers and containment devices, with only minor modifications. Equipment must be containerized to provide a buoyant and protective cover for over-water transport.

The sled is designed to transport any of four payloads: the Barrier equipment, the Lockheed Oil Recovery equipment, one ADAPTS package, or two ADAPTS packages. A moveable deck stop is provided to prevent forward movement of three of the payloads, Barrier, one ADAPTS, two ADAPTS, and to provide a guide for positioning the loads. The sides and aft end positions of the three loads are common and are guided by fixed deck frames. The Lockheed device must be elevated 2 ft above the deck to allow the pontoons to extend over the gunwales. Two frames are provided to support the Lockheed equipment.

There are two ways of launching the system (Figure F-4): (1) the payload can be loaded and secured in the sled on the pier and the assembled system then crane-lifted into the water, or (2) the sled and floating payload can be set into the water separately and then assembled. If a crane or lifting equipment capable of lifting the combined load is available, the first method is the more expedient. A four-legged sling is used in lifting the loaded or unloaded sled. A series of lift eyes are

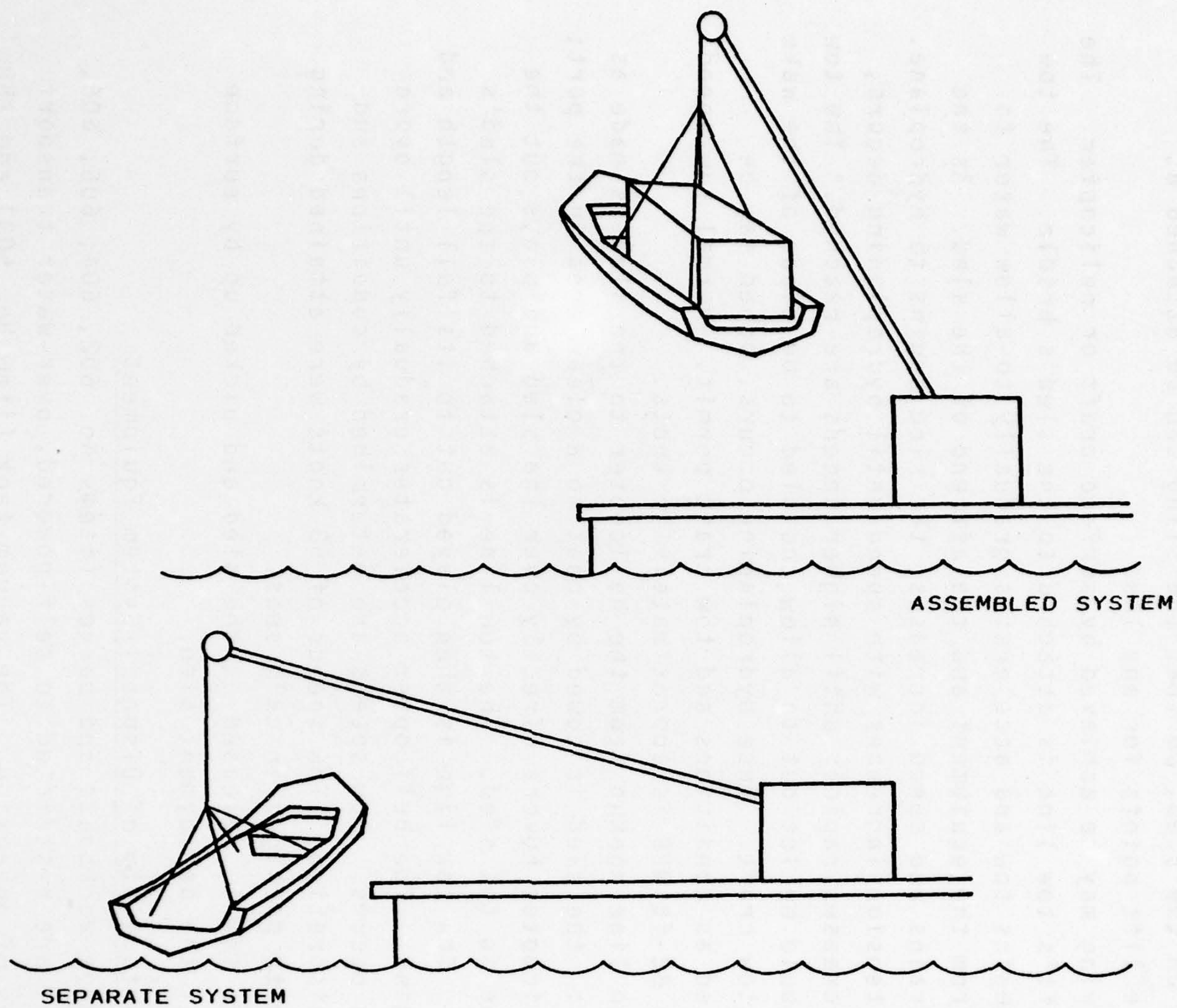


FIGURE F-4. LAUNCH METHODS.

From: Ward, Russell S., Towed Planing Sled for Delivery of Oil Pollution Control Equipment, USCG. Naval Coastal Systems Laboratory, Panama City, Florida, March 1976, p.

located on the sled, so that the sling can be attached at suitable lift points for any load.

Towing may be achieved by surface craft or helicopter. The tow craft's tow line is attached to the sled's bridle. The tow craft begins tow and accelerates gradually to allow water to drain from the equipment and the aft end of the sled. As the water drains and speed increases, the sled begins to hydroplane. Towing tension increases with speed until hydroplaning occurs, then decreases rapidly until higher speeds are reached. The tow line should be let out to allow the sled to be clear of the wake of the tow craft. Once hydroplaning occurs, speed may be increased as conditions and tow craft permit. Normal tow speed for the 82-ft WPB is approximately 16 knots.

Two line hookup from the helicopter to the sled is made as follows: the sled is towed by boat to a clear area in the port; the helicopter hovers directly over the sled and plays out the tow line to the sled. The tow line is attached to the sled's bridle. The tow line is then played out to its full length and tow begins. The helicopter accelerates gradually until hydroplaning occurs. Tow speeds are determined by conditions and pilot discretion. Tow speeds of 53 knots were attained during tests with packages in calm seas.

The tow is released at the sled and picked up by surface craft at the deployment site.

Transportability of Disposal System Equipment

Large workboats and barges (items No. 602, 604, 605, 606, and 608) are restricted to self-powered, over-water transport to sites of operation. The vacuum tank (item No. 503) and the flatbed trailer (item No. 513) must be pulled to the sites by the truck-tractor (item No. 514) over a high or improved road. The dump truck (item No. 501) must also be transported by roadway. All other equipment components not mentioned below are transportable by any means shown in Table E-1.

APPENDIX G

DISPOSAL BY CONTRACTORS
OFF-SITE FACILITIES

INTRODUCTION

The disposal hardware systems discussed in Section III (Task II Report) produce a relatively concentrated mass of oil and oil-stained solid debris that requires ultimate disposal. For those systems that include incineration, a solid residue is produced, which also requires disposal. Likewise, use of the hardware systems on hazardous chemical spill debris will generate a residual waste containing the particular hazardous chemical.

Land deposition of the residuals is the basic method available to the Coast Guard for on-site disposal of these residues. As noted in Section III, land disposal can be performed by two methods:

- Burial or
- Land cultivation (incorporation of the debris mass into the surface soil by mixing).

However, disposal of oil or hazardous chemical spill cleanup debris by the Coast Guard at the scene of cleanup operations may not always be practical for several reasons:

- An appropriate disposal site is not available.

- The quantity of spill debris is not sufficiently large to justify the cost of providing disposal equipment or personnel.

- The materials cannot be safely handled by mobile processing or land disposal equipment.

The spill debris mass could also be processed further to reduce its volume, detoxify its constituents, or otherwise improve disposability of the residues. Furthermore, there may be an opportunity to recover a portion of the spilled oil or chemical. Thus, the Coast Guard should consider use of established processing and/or disposal facilities near the spill

cleanup scene whenever on-site disposal of debris is not practical, or where off-site facilities would likely provide an environmental or cost advantage

The cost to transport the spill debris to off-site processing/disposal facilities, versus the costs for on-site disposal, should be considered. Strict adherence to the Environmental Protection Agency's criteria for land disposal facilities (now in draft form) may dictate careful Coast Guard site selection, operation, and long-term monitoring for on-site disposal of debris generated even during emergency cleanup activities. Costs for on-site disposal could thus be significantly higher than experienced in the past.

Also, the potential for environmental damage for on-site and off-site options should be assessed. The Coast Guard must determine whether deposition of a mass of spill debris at a new land disposal site (on-site disposal) would afford more environmental protection than transportation of the debris mass to a central, existing site (off-site disposal) some distance away from the cleanup site.

Off-site disposal options generally available to the Coast Guard are classified into three categories (see Figure G-1):

- Deposition on land or in water
- Treatment (to reduce debris volume or alter its form then land disposal of residue)
- Reprocessing for reuse.

Facilities for many of these disposal options are operated by private firms or contractors, although municipalities also provide waste disposal/processing service at established land disposal sites or incinerators in some localities.

Figure G-2 depicts a generalized flow diagram for deciding on off-site disposal options. General options are discussed below as they relate to Coast Guard needs during spill cleanup debris disposal operations.

DEPOSITION ON LAND OR IN WATER

Land Disposal

Debris recovered from spills in harbors, inland waters, and oceans consist mainly of large pieces of oil or chemically coated wood sorbents, kelp, and trash. Tables G-1 and G-2 describe the advantages and disadvantages of land disposal methods and their applicability to different types of debris.

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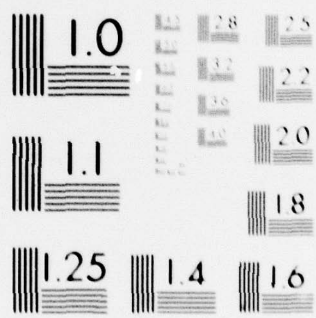

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DISPOSAL METHODS		HAZARDOUS CHEMICAL GROUPS (Appendix G)																
		S	VS	TS	TCS	TVS	LTSS	M	CM	VM	VCM	TM	TCM	TVM	TVCM	LTSM	G	DG
Recovery/ Reuse	Re-refining + Blending			x	x	x						x	x	x	x		x	x
	Heating Fuel	x	x				x	x	x	x	x					x	x	x
Treatment	Thermal	x	x				x	x	x	x	x					x	x	x
	Chemical Addition	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
	Biological	x	x				x	x	x	x	x					x		
	Physical/Chemical	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Physical	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Disposal	Incineration	x	x				x	x	x	x	x					x	x	x
	Landfilling	x	x				x	x		x						x		
	Burial		x	x	x	x			x	x	x	x	x	x	x			
	Deepwell Injection	x	x				x	x	x	x	x					x	x	x
	Lagooning/Evaporation		x							x	x							
	Engineered Storage			x	x	x						x	x	x	x			

Figure G-1. CONTRACTED DISPOSAL AT OFF-SITE FACILITIES: DISPOSAL MATRIX BY HAZARDOUS CHEMICAL GROUPS

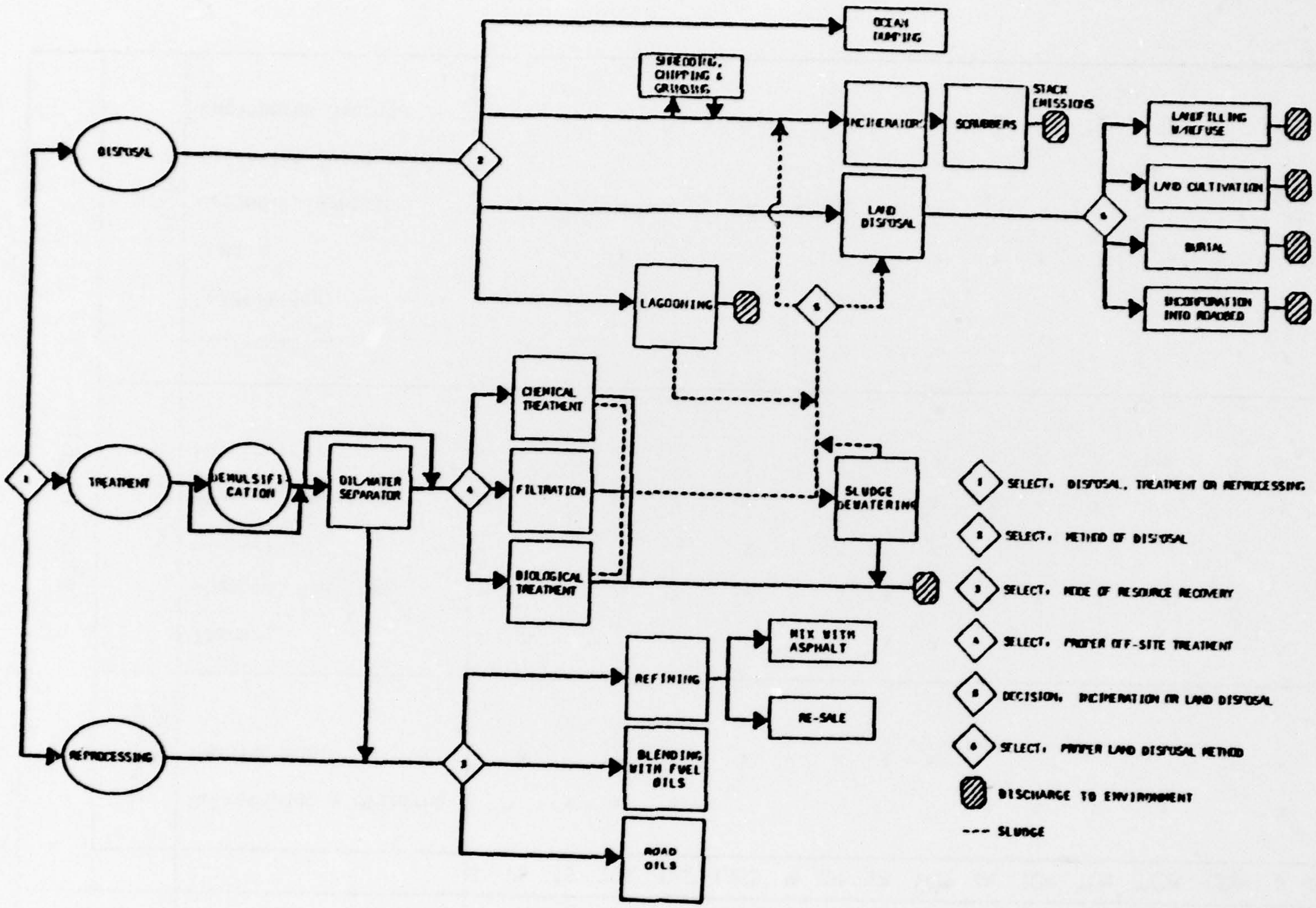

FIGURE G-2. DISPOSAL BY CONTRACTORS: OFF-SITE FACILITIES.

TABLE G-1. ADVANTAGES AND DISADVANTAGES OF ALTERNATIVE SPILL MASS DISPOSAL METHODS ON LAND

Disposal Method	Advantages	Disadvantages
Land cultivation	- Oil or biodegradable chemicals are degraded, minimizing long-term environmental threat. - Land surface reusable for debris or other purposes. - Soil properties may be improved.	- Opportunity for volatilization of oils or chemicals, thus, increased air pollution. - Periodic plowing required; frequency depends on soil types. - Relatively costly. - Stockpiling at disposal site may be necessary. - Degradation may be slow in cold, wet climates. - May be impractical to implement during inclement weather. - Potential for plant uptake of toxic chemicals.
Landfilling with refuse	- Minimal equipment needs. - Relatively low initial cost. - Minimal site preparation. - Many landfills available.	- Land is dedicated to disposal indefinitely. - Influx of spill debris may overtax available equipment and personnel. - Long-term pollution potential (e.g., leaching). - Long-term monitoring desirable.
Burial	- Spill-mass encapsulated, minimizes volatilization. - Operations complete relatively quickly. - Land surface can be returned to pre-disposal appearances.	- Land is dedicated to disposal indefinitely. - Materials remain undegraded for long periods with consequent long-term pollution potential (e.g., leaching). - Long-term monitoring desirable.

From: Stearns, Robert P., David E. Ross, and Robert Morrison, Oil Spill: Decisions for Debris Disposal. Long Beach, CA, SCS Engineers, 1977. Vol. 1.

TABLE G-2. APPLICABILITY OF LAND DISPOSAL METHODS TO DIFFERENT TYPES OF SPILL MASSES

	Debris Characteristic		
Disposal Method	Size of Solid Matter	Biodegradability	Oil or Chemical Content
Land cultivation	• Debris should be relatively small in size, less than 15 cm (6 in) e.g., oiled soils. Some larger vegetation may be acceptable, such as seaweed or brush. • Bulky matter may be separated for landfill disposal	• Predominantly fluids mixed with soils are best. Non-degradable materials or inorganic trash should not be present.	• Land cultivation best suited for debris heavily coated with biodegradable fluids.
Landfilling with refuse	• No limitation on size.	• No limitation on materials.	• In general, no limitation on debris oil or chemical content. Regulation agencies may object to disposal of heavily contaminated or high water content debris in a newer landfill where relatively little refuse is present to adsorb the liquids.
Burial	• In general, no size limitation. Bulky debris, such as poles, may pose operational problems. Also, disposal trenches may require widening to accommodate bulky items.	• No limitation on materials.	• No limitation on fluid content as long as site conditions are acceptable.

From: Stearns, Robert P., David E. Ross, and Robert Morrison, Oil Spill: Decisions for Debris Disposal. Long Beach, CA, SCS Engineers, 1977, Vol. I.

The cost of each debris disposal method is dependent on site-specific conditions such as the debris volume and composition, needs for access road construction, types of equipment used, and prevalent labor wage rates. Of course, land costs can vary significantly. In general, land cultivation costs are reportedly higher than the other methods because more equipment and personnel time are required. Landfilling with refuse is likely to be the least costly debris disposal method since the waste material is incorporated into an ongoing burial site; the equipment and personnel costs are also shared by others depositing wastes at the site.

The estimated range of unit costs to dispose of spill debris is shown in Table G-3. These costs do not include expenditures for land purchase or lease or any necessary land improvements. Transportation costs from the spill location to the disposal site are also not reflected.

Ocean Dumping

For years, ocean dumping seemed to hold the ideal solution for the disposal of wastes. Not only was it economical and convenient, but the properties of dilution and diffusion hid the fact that the oceans were becoming polluted. In the past 50 years, though, the sheer magnitude of ocean-dumped wastes and the increasing toxicity of these substances have led to clearly evident adverse environmental impacts.

With the rise of the environmental consciousness in the 1960's and concomitant widespread media coverage, legal action to reverse the consequences of pollution was promulgated. In 1972, the Marine Protection, Research, and Sanctuaries Act, which essentially put an end to unrestricted ocean dumping of waste materials, was passed by Congress. Otherwise known as the Ocean Dumping Act, this legislation provided the regulation, surveillance, enforcement, and research necessary to encourage alternatives to disposal. Under the Act, a permit system authorizes the dumping of selected wastes such as dredged materials, containerized industrial wastes, some refuse, sewage sludge construction and demolition debris. This system is administered by the Environmental Protection Agency, and includes the responsibility for the designation of specific sites and disposal procedures (2). Among the materials prohibited from disposal are chemical, biological, and radiological warfare agents and high-level radioactive wastes; explosives; and sewage sludge.

Materials from oil or chemical spills are not authorized to be dumped in the oceans. Unless debris soaked by oil or floating hazardous chemicals is properly encapsulated and sunk, ocean dumping of such waste will not meet EPA standards. It is

TABLE G-3. COMPARISON OF LAND DISPOSAL METHODS FOR OIL SPILL DEBRIS

Method	Operating Factors: Equipment Needs	Operating Factors: Flexibility	Environmental Factors	Estimated Costs
Land cultivation	- tractor - rototiller, disc, harrow, or plow	- adaptable to many areas - requires no special skills - access road may be req'd	- minimal hazards if runoff controlled; - no danger to groundwater; - no spontaneous combustion problems; - land may be tied up for disposal only temporarily (2-3 years).	$4.84 to $9.68 per cy (not including cost to construct access roads, if any)
Landfilling with refuse	use equipment available at landfill; generally a D-6 sized track dozer or larger	- for relatively small volumes of debris most landfills can readily accept; - many landfills available; - stockpiling usually unnecessary.	- improper landfill location may cause undue threat of oil pollution; - refuse can act as sorbent to impede flow of oil and contaminated water from site; - possibility of spontaneous combustion; - continuous long-term dedication of land to waste disposal.	$0.96 to $3.63 per cy
Burial	1 - D-8 sized tractor or larger. 1 backhoe may be necessary.	- stockpiling may be necessary; - access road may be required.	- oil will remain undegraded at site for more than 100 years; - a plot of land, heretofore unused for waste disposal, will be dedicated for such long-term usage.	$1.81 to $6.05 per cy (not including cost to construct access road, if any)

From: Stearns, Robert P., David E. Ross, and Robert Morrison, Oil Spill: Decisions for Debris Disposal. Long Beach, CA, SCS Engineers, 1977. Vol. 2.

likely that the high cost of encapsulation and subsequent transfer to an ocean dump site make ocean dumping an economically impractical alternative as an off-site disposal option.

TREATMENT

Presently, there are several options available to the Coast Guard for the off-site treatment of spill debris. These processes can be used to reduce waste volume and/or to alter the form of the spill mass to facilitate subsequent ultimate disposal. The following processes are briefly discussed below:

- Shredding
- Incineration
- Physical-chemical treatment
- Biological treatment.

Shredding

A shredder may be used to reduce the size of large objects in the spill debris, and to produce uniform sized particles for disposal. Land cultivation, for instance, works optimally if debris size does not exceed 6 in. in diameter. Fire hazard is also reduced if materials are shredded and landfilling compaction densities for bulky wastes are increased. Shredder facilities are often on location at landfilling sites, and also may be used in conjunction with incinerators. While chippers and small shredders could be included in a debris disposal hardware system, use of larger permanent shredders off-site may be necessary to process large bulky spill debris, especially if a significant quantity of debris is collected.

Incineration

Incineration is the controlled process of burning organic material to reduce its volume.

Incineration is often an effective method for destroying oil and hazardous chemicals collected from spills. It completely destroys the organic fraction of liquid, solid, and gaseous wastes so that the reduced fraction of inorganic ashes or residue can be disposed of more easily. Volume of solids are reduced up to 90 percent.

Oil or chemical spill debris can be accepted at many industrial incinerators, depending on the specific chemicals present in the debris, debris moisture content, and the incinerator design. Oils or hazardous floating chemicals which have a flash point below 50^{0} and 100^{0} would indicate that a substance is potentially explosive if subjected to additional heat. Thus, care should be taken in handling this substance at an incinerator.

Combustibility level ranges between 100^oF and 200^oF, and includes those substances that would be most amenable to incineration.

Special liquid waste incinerators may be available off site. For debris with a relatively high moisture content, used auxiliary fuel would be necessary to drive off water before the oil or chemical could be incinerated. It should also be noted that debris-containing seawater, which contains 3.5 percent by weight of dissolved salts, may present special problems in incineration. Seawater can give off contaminants when decomposed through incineration, and the salt content may induce corrosion and fluxing within the combustion chamber (7).

Several types of incinerators applicable to the destruction of oil and hazardous chemicals from oil spills are described in Table G-4. Municipal incinerators are not included in this text, however, because the following disadvantages generally preclude their use in the destruction of debris and liquid from a spill.

- They are not equipped to burn at a temperature high enough to destroy chemicals having a flash point above certain temperatures.
- The combustion temperature of oil is higher than that of domestic refuse and exceeds the capability of a municipal incinerator refractory walls. (This problem can be countered by mixing the oil in small proportion to the refuse, but the extra time and cost may not be justified on an economic basis).
- They do not usually incorporate the proper scrubbers and emission devices to control particulates given off by certain chemical substances.
- Corrosive elements in salt water can attack incinerator surfaces.

Physical-Chemical Treatment

Available off-site physical-chemical treatment facilities may also be applicable for spill debris. There are several physical-chemical treatment schemes that may be used in combination or separately to achieve a desired result. Voluminous sludges are often produced by such processing, however, which must then be removed by clarifier or flotation units and ultimately brought to a land disposal facility.

Demulsification is the initial unit in most physical-chemical treatment systems for waste streams containing oils. It consists of a contact tank which usually preceeds a gravity separation unit. This system breaks up the liquid emulsions,or prevents them from forming by chemical, mechanical, or electrical means.

TABLE G-4. INCINERATORS APPLICABLE TO THE DESTRUCTION OF OIL AND HAZARDOUS WASTE FROM SPILLS*

Incinerator	Process Principle	Application	Combustion Temperatures	Residence Times	Economics
Cement Kiln	Slowly rotating cylinder mounted at slight incline to horizontal. Tumbling action improves efficiency of solid waste destruction.	Most organic wastes; well suited for solids and sludges; liquids and gases fired through auxiliary nozzles. Accepts substances containing chlorine.	Can be fired as high as 3,000°F.		
Cyclonic Furnace	Waste material is placed at the periphery of the rotating hearth. The combustion air and auxiliary air are injected tangentially into the combustion chamber causing the gases to mix and move the material to combustion.	Sludge	1,500°F		Low capital costs
Fluidized Bed Incinerator	Wastes are injected into a hot agitated bed of inert granular particles; heat is transferred between the bed material (often sand) and the waste during combustion.	Most organic wastes, ideal for liquids, also handles solids and gases.	750°-870°C (1,400°-1,600°F)	Seconds for gases, liquids; longer for solids.	Reported capital costs - For liquids $383-845 liter/hr ($1,331-$3,194/gal/hr). For solids - $146-$386/Kg/hr ($67-$173/lb/hr). Operating cost - approximately $37/t ($33/ton) dry solids. Project operating costs - for liquids - $.0033 - $.028/liter ($.01-0.11/gal.)

*Adapted from Scurlock, A.C., A.W. Lindsey, T. Fields, Jr., D.R. Huber, Incineration in Hazardous Waste Management, U.S. Environmental Protection Agency, 1975. Costs adjusted to 1978 dollars.

Table G-4. (continued)

Incinerator	Process Principle	Application	Combustion Temperatures	Residence Times	Economics
Liquid Injection Incinerator	Vertical or horizontal vessel; wastes atomized through nozzles to increase rate of vaporization.	Limited to pumpable liquids and slurries (750 SSU or less for proper atomization).	650°-1,650°C (1,200°-3,000°F)	.1-1 second	Operating cost - $.33-$87.00/1,000ℓ ($1.33-$333.00/gal).
Molten Salt Process	Wastes are injected into a bed of molten salt (usually sodium carbonate) where combustion occurs; salts may react with and retain off gases.	Most organic wastes.	810-980°C (1,500-1,800°F)	3/4 second average	Proposed investment cost for complete portable 230 Kg (500 lb)/hr unit, $665,500 for a 90 Kg (200 lb)/hr unit with salt regeneration, $1,064,800.
Multiple Hearth Incineration	Solid feed slowly moves through vertically stacked hearths, gases and liquids fed through side ports and nozzles. Current applications largely in sewage sludge incineration.	Most organic wastes; well suited for solids and sludges, also handles liquids and gases.	(With sewage sludge) drying zone - 320-540°C (600-1,000°F). Incineration zone - 760-980°C (1,400-1,800°F).	Up to several hr for solids.	Basis dry solids (sludge 75% moisture). Installed cost - $73-$658 Kg/hr ($33-300/lb/hr) capacity. Operating cost - $4-$32/t ($3-$30/ton).
Rotary Kiln Incineration	Slowly rotating cylinder mounted at slight incline to horizontal. Tumbling action improves efficiency of solid waste destruction. Technology adapted from lime processing	Most organic wastes; well suited for solids and sludges; liquids and gases fired through auxiliary nozzles.	810°-1,650°C (1,500-3,000°F)	Several seconds to to several hr (liquids and gases-short, solids much longer).	Installed capital - $3,727-$14,907/daily t ($3,328-$13,310/daily t). Kiln maintenance - 5-10% of installed cost/yr.

Table G-4 (continued)

Incinerator	Process Principle	Application	Combustion Temperatures	Residence Times	Economics
Wet Oxidation	Oxidation of organic materials in a liquid state under high pressure at moderate temperatures. Sulfer, nitrogen, and halogen breakdown products are retained in liquid effluent.	Soluble and water miscible organic wastes.	316,000-1,758,000 Kg/m^2 gauge (450-2,500 psig)	10-30 min	Total treatment costs (capital and operating) - \$.033-0.70/liter (.00.-.03¢/ga). Equipment costs - \$266,200-\$798,600 (75Lpm (20gpm) system).
Single Chamber Vapor Recovery System	Vapor and liquid are co-mixed and oxydized to form carbon dioxide. The mixture is then fed to the boiler and steam is the result. Capacity is 4,000 gal per day.	Light petroleum products, light distillates, oxygenated solvents (alcohol, Jet Fuel No. 4). It also accepts unlimited amounts of sea water.			

#Similar to a model manufactured by Hirt Enterprises, Los Angeles. This particular equipment was built by Industrial Tank Environmental Corporation, Martinez, California.

Gravity separation equipment includes API separators, simple tanks with skimmers, and various skimming clarifier designs which are effective in removing large amounts of free oil from contaminated water. This type of equipment will not remove soluble oil fractions and many types of emulsions, but it is efficient in removing free and some emulsified oils.

Chemical agents, including sulfuric acid, alum, or ferric chloride, can also be used for treatment purposes. The chemical agent is fed into a flocculation tank in which a large percentage of pollutant composition is allowed to coagulate. This component can then be separated in a sedimentation basin and the treated effluent is conveyed for additional treatment.

Filtration processes may also be used in conjunction with these other treatment systems. Although filters are used today for wastewater treatment, relatively few were deemed to be useful for treating fluids from recovered spill masses. Each type of filter, however, is represented by equipment which has been demonstrated as effective in the treatment of oily wastes. Filters used in waste treatment operations belong to the following three general categories:

- Conventional filters
- Ultra- and micro-filters
- Reverse osmosis systems
- Activated carbon.

Conventional filters are typically applied to particles larger than 3 to 5 μ. Ultra-filtration is applied to particles in the range between 0.003 and 1 μ. Reverse osmosis is capable of extracting some viruses, macromolecules, ions, and other particles less than 0.05 μ in size. Activated-carbon filtration is usually thought of as a polishing process for water that has already been treated. The carbon is used to remove dissolved organic matter that remains.

Biological Treatment

Conventional applications of biological treatment to industrial organic and hazardous wastes include most techniques used for municipal waste treatment. Such schemes include activated sludge, aeration basins, trickling filters, stabilization ponds, and landspreading.

Biological processes have limitations in their applicability to oil and floating chemical removal. Biological organisms are efficient in oxidizing soluble organic compounds including some dispersed or emulsified oil. Large amounts of free oil or floating chemicals must be avoided as they coat the biological flocs, prohibit efficient oxygen transfer within the biomass, and reduce the ability of the larger particles to settle out of the mass.

Therefore, while biological treatment processes may be required to meet discharge standards, care should be taken to design pretreatment facilities capable of removing oil or chemicals to concentration levels where biological treatment processes may be effective. Physical and chemical pretreatment is therefore often an important predecessor to biological treatment systems where concentrated waste products are involved.

Many waste disposal companies and municipalities use stabilization ponds as a secondary process for treating their wastes. Anaerobic and/or aerobic bacteria present within the ponds are allowed to break down the organic fraction of the waste. A potential liability of this system is the possible leakage of harmful waste products into the surrounding environment. No instances of spill debris disposal by lagooning have been reported, although the method has often been used for spent drilling muds and other oil field wastes.

All of the treatment methods mentioned above are available at off-site facilities. These processes serve to reduce waste volume and/or detoxify the waste constituents in order to improve the ultimate deposition of the residues. The residual waste can then be disposed of most conveniently by land disposal methods.

REPROCESSING

Several reprocessing techniques (see Figure G-3) are in use by waste disposal contractors and rerefiners for recovering oil and hazardous chemicals. The recovered oil or chemicals may be used for its original intended purpose (if sufficiently pure), or for alternative purposes such as road oil, lower grade fuel, or roofing felt additives. Waste disposal companies which offer such services are located throughout the United States.* Some of the reprocessing techniques used by waste disposal companies are described below.

Gravimetric/Thermal

This process consists of the simple heating of the oil mixture to 180 to 200°F, at which point steam is injected and emulsion-breakers or solvents are used to help to separate the constituents. When the steam is shut off, the water and debris naturally settle to the bottom of the processing tank, and oil is skimmed off the top. This oily water usually contains 2 to 3 percent water when it is heated again to a temperature of 250°F and filtered. The result is an oil that can be used for heating.

*See Hazardous Waste Management Facilities in the United States - 1977, U.S. Environmental Protection Agency, January 1977.

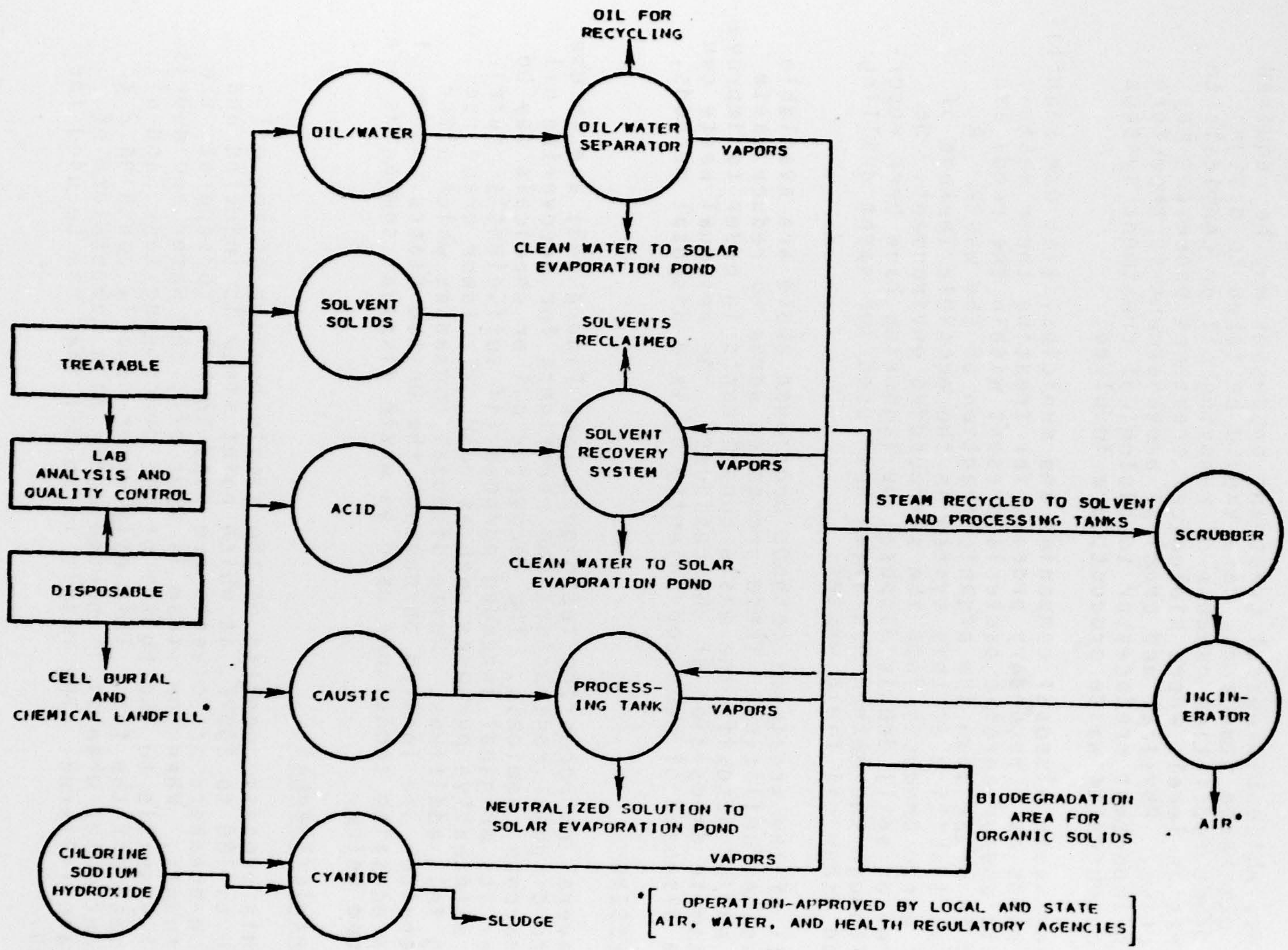

FIGURE G-3. TREATMENT OPTIONS USED BY WASTE DISPOSAL COMPANIES.

Air Agitation

Oil/water separation can also be achieved by shooting jets of air through the oil/water mixture, which results in a fine bubbling action that carries the oil to the surface. Emulsion breakers can then be used to break the surface tension in the water. If sulfanate is present, however, separation becomes difficult.

Centrifugation

A centrifuge is used to separate materials having different densities. If the spill mass has a high solids content, the process can be very abrasive to the machinery; however; the oil must be relatively light. Denser oil is difficult to remove from the apparatus.

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